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Findings of a study of the nation's manpower requirements to 1975 are presented. Part I, on the employment outlook, consists of a 10-year projection of manpower requirements by occupation and by industry prepared by the Bureau of Labor Statistics and an analysis of the growth prospects and the state of fiscal policy in the United States economy as of mid-1965 by George Perry. Part II, on the technological outlook, presents (1) a description of the state of computer development and use and speculation on future developments in the general use of computers, by Paul Armer, (2) a description of the specialized art of information processing networks by Merril Flood, (3) an examination of computer applications to industrial process control which reveals an exaggeration both of the number of process control installations and of their employment impact, by Tom Stout, (4) an assessment of computer applications in the fabricating industries, by Eugene Schwartz and Theodore Prenting, which reveals similar exaggerations with the exception of rapid growth in numerical control of machine tools, and (5) ways of projecting future productivity by the Bureau of Labor Statistics. Numerous tables and graphs present statistical data. Other appendixes to VT 003 962 are VT 003 961 and VT 005 794-VT 005 797.

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THE OUTLOOK FOR TECHNOLOGICAL CHANGE AND EMPLOYMENT

Appendix Volume I

TECHNOLOGY AND THE AMERICAN ECONOMY, The Report of the Commission

Studies prepared for the National Commission on Technology, Automation, and Economic Progress • February 1966

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Appendix Volume I

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The Report of the Commission

Studies prepared for the National Commission on Technology, Automation, and Economic Progress • February 1966

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PREFACE

This volume is the first of six appendix volumes to Technology and the American Economy, the report of the National Commission on Technology, Automation, and Economic Progress. The full series of appendix volumes is as follows:

I. The Outlook for Technological Change and Employment
II. The Employment Impact of Technological Change
III. Adjusting to Change
IV. Educational Implications of Technological Change
V. Applying Technology to Unmet Needs
VI. Statements Relating to the Impact of Technological Change

This volume contains seven studies dealing with the outlook for technological change and employment, prepared by independent experts at the request of the Commission.

Part I, on the employment outlook, consists of two studies. The first is a 10-year projection of manpower requirements by occupation and by industry prepared by the Bureau of Labor Statistics. In the second study, George Perry has analyzed the growth prospects and the state of fiscal policy in the United States economy as of mid-1965. His analysis of the fiscal actions required to bring unemployment to targets of 4 percent and 3 percent by 1967 and 1968 has been outstripped but not faulted by subsequent events.

Part 2 of this volume, on the technological outlook, consists of five studies. Paul Armer describes the present state of the computer art and gives a solid basis to speculation about future developments in the general use of computers. Merril Flood provides a similar perspective in the more specialized art of information processing networks. Tom Stout examines the state of computerization in process control industries and finds both the number of such installations and their employment impact to be exaggerated. Schwartz and Prenting assess the state of computerization in fabricating industries with similar results but with notation of the rapid growth of numerical controls in machining. Exploring for ways to project future productivity, the Bureau of Labor Statistics assessed the possibility of using the productivity of the most advanced plants in an industry as an indication of the average productivity likely in the industry at some future point. Though more study is needed, it did appear from a limited number of case studies that a 7-year "catch-up" was involved which might be usable for forecasting purposes.

Additional studies prepared for the Commission are contained in Appendix Volumes II, III, IV, and V. Appendix Volume VI contains a group of statements by various interested organizations and individuals in response to a request from the Commission for their views on the impact of technological change.

Though the Commission does not necessarily endorse the information and views in these documents, it considers them of sufficient value to have directed their publication.

This volume was edited and prepared for publication by Judith Huxley.

GARTH L. MANGUM,
Executive Secretary.

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OTHER APPENDIX VOLUMES PRINTED UNDER SEPARATE COVERS

II. The Employment Impact of Technological Change
III. Adjusting to Change
IV. Educational Implications of Technological Change
V. Applying Technology to Unmet Needs
VI. Statements Relating to the Impact of Technological Change

Part 1

THE EMPLOYMENT OUTLOOK

206-754—66—vol. I——2

AMERICA'S INDUSTRIAL AND OCCUPATIONAL MANPOWER REQUIREMENTS, 1964–75

Prepared for the Commission
by the
Bureau of Labor Statistics
U.S. Department of Labor

PREFACE

This report presents the findings of a study of the Nation's manpower requirements to 1975. This study was conducted by the Bureau of Labor Statistics at the request of the National Commission on Technology, Automation, and Economic Progress, and is an outgrowth of the Bureau's continuing programs of research on future manpower requirements and resources, and on the impact of technological change on employment. The study was prepared in the Bureau's Office of Manpower and Employment Statistics, Harold Goldstein, Chief.

The study which comprises this report was carried out in the Bureau's Division of Manpower and Occupational Outlook, under the supervision of Sol Swerdloff, Chief. General planning, direction and coordination of the study was done by Howard V. Stambler, Special Projects Director. Allan F. Salt supervised the preparation of the sections on industry and occupational projections, assisted by Russell B. Flanders, William J. Kelley, and Joe L. Russell. The multiple regression analysis used as the preliminary framework for the industry and occupational projections was developed by James W. Longley.

This report makes extensive use of research conducted as part of other programs of the Bureau of Labor Statistics. Projections of the labor force were prepared by Sophia Cooper, Chief, Division of Population and Labor Force Studies, with the assistance of Denis Johnston (see "Labor Force Projections for 1970–80," *Monthly Labor Review*, February 1965). Information on trends in output per manhour and on technological trends in major industries was provided by the Office of Productivity and Technological Developments, Leon Greenberg, Chief. Especially valuable was information collected in connection with that Office's *Technological Trends in Major American Industries* (BLS Bulletin 1474), prepared under the direction of Edgar Weinberg, Chief, Division of Technological Studies, assisted by John Macut and John Shott. Extensive use was also made of information on the occupational composition of industries prepared by Harry Greenspan, James Metcalf, and Robert Dempsey of the Division of Occupational Employment Statistics, Robert B. Steffes, Chief. Additional information was derived from preliminary projections of the U.S. economy to 1970 developed by the Division of Economic Growth, Jack Alterman, Chief, as part of the Interagency Growth Study Project. The Interagency Growth Study Project, which has as its major objective the development of an analytical framework for exploring the implications of alternative assumptions regarding rates and patterns of long-term growth on a number of important economic problems, uses an input-output matrix as a basic methodological tool in tracing the impact of changes in final demand on industry output and employment.

CONTENTS

America's Industrial and Occupational Manpower Requirements, 1964–75

Introduction

In line with their assigned responsibility to identify and describe the impact of technology and economic change on employment, including new job requirements and the major types of worker displacement, both technological and economic, which are likely to occur during the next 10 years, the National Commission on Technology, Automation, and Economic Progress in mid-1965 asked the Bureau of Labor Statistics to prepare projections of manpower requirements in 1975 by industry and occupation and for certain specified groups of workers. In response to that request, the Bureau of Labor Statistics conducted the study which comprises the following report.

The report is divided into five major parts. Part I presents a discussion of the assumptions underlying the projections of industry and occupational requirements. It also presents a brief description of the methodology used to develop the projections and explains the limitations of the resulting projections.

Part II presents projections of each industry's manpower requirements in 1975. Past trends in employment are discussed, and projections of manpower requirements to 1975 are presented along with a discussion of the factors expected to influence future manpower requirements. At the request of the Commission, each statement includes a brief description of the significant technological changes expected to influence employment in the years ahead. Part II also contains a discussion of how economic conditions (as measured by the level of unemployment in the economy as a whole) affect differently the individual industry divisions.

Part III presents the projections of manpower requirements in 1975 for the major occupational groups and for a selected list of individual occupations. Like the industry statements in Part II, each occupational statement provides information on past trends in employment, presents the projections of manpower requirements to 1975, and discusses the factors affecting the occupation. Each statement also includes a description of the impact of changing technology on future employment requirements.

Part IV presents a summary discussion of the factors which influence occupational and industry requirements in the American economy as a whole, including different rates of employment growth among industries, population growth, government expenditures, institutional factors, and automation and other technological changes. The factors underlying past occupational changes are examined, and, for illustrative purposes, the impact of past technological changes on occupational employment in several industries is discussed in detail.

Part V illustrates the effect of the projected occupational requirements on important subgroups of the labor force—nonwhite workers, younger and older workers, and women. Utilizing the occupational projections for the broad groups presented in Part III, the effect of the Nation's changing occupational structure on the opportunities for nonwhites is illustrated, first on the assumption that nonwhite occupational "penetration rates" will remain at 1964 levels, and, second, on the assumption that they will change at the rate at which they have changed in recent years. The resulting estimates are then compared with preliminary projections of the nonwhite labor force, in order to evaluate the implications of the Nation's changing occupational structure for employment of nonwhite workers. Part V also shows what the effect of the changing occupational requirements would be if the age and sex distribution of occupations were to be the same in 1975 as in 1964. This includes a comparison of the illustrative projections of occupational requirements in 1975 by age and sex with the supply of workers likely to be available at that time.

Summary

Projections of the manpower requirements of the United States to 1975, under the assumption that the unemployment rate will be 3 percent, as suggested by the National Commission on Technology, Automation and Economic Progress, lead to the following major findings:

1. Given the projected growth of the labor force, the assumptions made imply that 88.7 million persons would be gainfully employed in 1975, 18.3 million more than in 1964—an average increase of nearly 1.7 million annually in this 11-year period. (This compares with an average annual increase of 1.1 million attained from 1960 to 1965, and 1.8 million from 1964 to 1965.)

2. While it is possible to assume a variety of patterns of economic growth, depending on shifts in investment and consumer expenditure patterns and changes in emphasis in Government programs, the type of economy projected in this report is one characterized by an extension of the basic patterns which developed in the postwar period. Farm employment is expected to decline by about 1 million; all other employment is expected to increase by over 19 million. For nonfarm "goods producing" industries—manufacturing, mining, and construction—a moderate increase in manpower requirements of about 17 percent is projected, a rate of increase somewhat faster than that which occurred in the 17-year period, 1947 to 1964. Requirements in the "service producing" sector as a whole—trade, finance, government, services, and transportation and public utilities—are expected to increase more rapidly, by 38 percent, also somewhat faster than over the past 17-year period. Among these fast-growing service-producing industries, the only one expected to have only a small increase in requirements is transportation and public utilities; in this industry, a reversal of the downward trend of the past 17 years is expected.

3. The effect of these industry trends will be to continue recent changes in the industrial composition of the economy. Government and services will increase sharply as a percent of the total; construction and trade will also increase their share. On the other hand, the relative importance of manufacturing and transportation and public utilities will decline slightly, and the relative size of agriculture and mining will continue to decline sharply. Taking the broad "goods" and "services" sectors as a whole (and including agriculture, with its self-employed as well as its wage and salary workers, in the former), the goods sector will decline from about 41 percent of all jobs in 1964 to 36 percent in 1975; the service sector will increase its share of manpower requirements from 59 to 64 percent. (If self-employed persons in nonagricultural industries were added to the above comparison, the services sector would have a slightly larger share in both years.)

4. The occupational requirements of the economy will change substantially as a result of both the differential growth rates of industries and the technological developments affecting the occupational requirements of each industry. Concern has been expressed that the impact of technological and industrial change will drastically curtail employment opportunities for less-skilled workers. *The major conclusion of this study, which takes into account every technological change in American industry that can be identified and makes a careful appraisal of its potential effect on employment, is that the overall demand for less-skilled workers will not decrease over this 11-year period, although it will decline somewhat as a percentage of the total.* Needs for nonfarm laborers in 1975 will be roughly the same as in 1964, although they will decrease from 5.2 to 4.2 percent of total manpower requirements. More than 3 million additional service workers will be required, and their share of total jobs will rise from 13.2 to 14.1 percent. Nearly 2 million more operatives will be neded; their share will, however, decline from 18.4 to 16.7 percent. An overall decline of more than 900,000 in the employment of farm workers is expected (mostly among farm owners rather than farm laborers), and the share of farm jobs in the total is expected to decline from 6.3 to 3.9 percent.

The greatest increase in requirements will be for professional and technical workers; more than 4½ million additional personnel will be required, an increase of 54 percent. The white-collar group as a whole is expected to expand by nearly two-fifths, and to constitute 48 percent of all manpower requirements in 1975. The blue-collar occupations are expected to expand at less than half this rate, and will constitute 34 percent of all requirements. A rapid expansion in requirements for service workers is anticipated—a 35-percent increase in employment, bringing this group to about 14 percent of the total.

5. These changes in occupational requirements have significant implications for certain groups in the labor force.

Nonwhite workers are disproportionately concentrated in less-skilled occupations that now have higher-than-average unemployment rates and that are not expected to grow as rapidly as the more-skilled occupations. If nonwhites do not gain access to white-collar and skilled jobs at a faster rate than they have in recent years, they will continue to have more serious unemployment problems than their white fellow-citizens.

Young workers, another group with high unemployment rates, are also concentrated in the slower growing less-skilled occupations. The supply of young workers will grow faster in the next decade than the labor force as a whole. If we are to avoid continued high unemployment rates for youths, industry may have to take such steps as lowering the minimum age at which they hire workers for certain occupations, using younger workers as aids or assistants to the relatively more scarce mature and experienced workers, or promoting them faster to more-skilled jobs.

Women workers, on the other hand, although they, too, are increasing faster than the labor force as a whole, are already concentrated in the more rapidly growing white-collar occupations. If no changes take place in their proportionate share of jobs in the various occupations, they will have no more serious employment problems than they now have. However, men are increasingly competing for some of the jobs women have traditionally held in such occupations as teaching, social work, and library work. If this continues, women workers may have to find additional employment outside the occupations in which they have traditionally predominated.

PART I. ASSUMPTIONS AND METHODOLOGY

The industry and occupational projections presented in this report result from the Bureau of Labor Statistics' continuing program of research in future occupational and industry manpower requirements and resources. The occupational outlook program of the Bureau, under which the projections were developed, stemmed originally from the report of the Advisory Committee on Education appointed by President Roosevelt, which in 1938 recommended that an occupational outlook service be set up in the Bureau of Labor Statistics to make studies and provide information for use of individuals choosing a career, and for the use of those responsible for planning education and training programs. Since its inception, the occupational outlook program of the Bureau has produced hundreds of bulletins, studies, and reports on the Nation's manpower needs and resources. (For a selected listing of publications, see *Counselor's Guide to Occupational and Other Manpower Information—An Annotated Bibliography of Selected Government Publications*, BLS Bulletin 1421, November 1964.)

In its two and a half decades of industry and occupational research, the Bureau of Labor Statistics has systematically accumulated and analyzed manpower information on such topics as employment trends for major industries and for most major occupations, and on the many factors affecting employment; employment effects of a great many long-term programs of Government agencies, including those for defense, highways, scientific research, space technology, medical care, and education; and changes in industry and occupational requirements as they have been affected by these factors and by changing technology. The projections presented in this report reflect and stem not only from this continuing program of occupational outlook research, but also from the Bureau's program of research on productivity and technological developments. It should be noted that although projections for many of the occupations and industries covered in this report have been published by the Bureau of Labor Statistics—many of them fairly recently—the projections presented here reflect a comprehensive and up-to-date reevaluation of the Bureau's occupational-industry projections.

Projecting future manpower requirements is a difficult and hazardous task. Manpower requirements can be affected by a great variety of possible events: new scientific discoveries and inventions, national and international political and social developments, natural catastrophes, and the vagaries of consumer preferences. Even if these influences were all that had to be considered, the task would still be difficult, since our knowledge of past economic and manpower trends and of the forces governing their interrelationships is incomplete and imperfect. In order to fully understand these projections, it is necessary to examine the assumptions which underly them and the methodology through which they were produced. The following sections of Part I provide such an examination.

Assumptions

Perhaps the most significant determinants of any manpower projection are the basic assumptions describing the expected nature and composition of the economy in the target year, in this case, 1975. Thus, in using the manpower projections developed for this report, the underlying assumptions should always be borne in mind.

A major group of assumptions underlying the projections is that relating to the level of economic activity in 1975. The size and composition of the labor force—one determining factor—is assumed to change by 1975 as projected by the Bureau of Labor Statistics in the February 1965 *Monthly Labor Review*.[1] These projections indicate that the total labor force in 1975 will be 94.1 million. Since the target year 1975 is assumed to be one of peacetime conditions, similar to those immediately prior to the Vietnam buildup, the assumption as to the size of the Armed Forces in 1975—2.7 million—represents no significant change from the number of persons in the military services in 1964. The net result of the utilization of these assumptions is that the civilian labor force is projected at 91.4 million in 1975.

Another major assumption in the group is that on the level of unemployment in 1975. At the explicit request of the National Commission on Technology, Automation, and Economic Progress, the basic set of assumptions developed for this report assume an unemployment rate of 3 percent in 1975. However, since industries and occupa-

[1] "Labor Force Projections for 1970–80," *Monthly Labor Review*, February 1965. These projections were adjusted upwards to reflect the larger labor force under 3 percent level of unemployment.

tions are affected differently by cyclical factors (for which the rate of unemployment may be a proxy), Part III provides, for illustrative purposes, an indication of which broad industry groups are most affected by changes in the business cycle as reflected in varying levels of unemployment, so that the reader interested in the implications of alternate assumptions can make the appropriate allowances.

Given the above assumption, 88.7 million of the 91.4 million civilian workers will be employed in 1975. (A more detailed discussion of civilian employment in 1975 appears in Part II.)

Other major assumptions which underly the projections in this report are: (1) that there will be no war or other cataclysmic event which would substantially alter the rate and nature of economic growth; (2) that National Security expenditures in 1975 (excluding space) will not be significantly different from what they were in 1964 (in dollar terms); (3) that economic and social patterns and relationships in our society, including patterns of consumption, will continue to change at about the same rate as they have in the recent past; and (4) that the scientific and technological advances of recent years will continue and that research and development expenditures will continue to grow, although at a slower rate than during the decade of the 1950's and early 1960's. Other more specific assumptions underlying the demand for manpower are discussed as they apply specifically to the industry and occupational projections.

Methodology

In developing projections of manpower requirements used by the Bureau in its own occupational outlook program and expanded for this report, different methods of analysis were used for individual industries and occupations. Varying techniques are required not only because different factors affect individual industries and occupations, but because differences exist in the amount and quality of data available for analysis. The broad pattern of research, however, was generally the same in each of the detailed industry and occupational studies, described below.

Methodology of Industry Projections. In developing the industry projections, the factors affecting employment in each industry were analyzed, both separately and as part of an overall framework. In the separate industry analyses, one of the most significant factors affecting employment in each industry was the prospective level of demand for the products of the industry, and the consequent effect of changes in demand on employment. Other important factors which were considered were expected technological changes as they affected output per man-hour, and changes in hours of work.

More specifically, in projecting the activity or production level of an individual industry, it was necessary to first establish the nature of the demand for the industry's products or services and the relationship of this demand to the growth of the whole economy. Obviously, an industry producing products directly for consumers will have a different type of demand function than an industry which is making raw materials to be used as a component for further manufacturing.

An example of the analysis undertaken for one industry may serve to clarify the procedure. In projecting the production for steel in the analysis of the primary metals industry, for example, consideration was given to the expected increase in population and the trend in per capita steel output. Total requirements for steel depend on the requirements projected of each of the principal steel-using industries, such as the automobile, construction, electrical appliances, machinery, and containers industries; competition with steel by other materials such as aluminum and plastics; and the import-export balance for steel. In effect, it was necessary to project the output of both domestic and foreign users of American steel in order to estimate total steel requirements. Future industry steel production was then translated into overall manpower requirements by estimating changes in man-hours per unit of output for the industry, and making assumptions as to changes in hours of work. In this industry, as in others, extensive use was made of preliminary data from the input-output tables prepared by the interagency economic growth project.

In addition to the detailed and comprehensive analysis of each industry, a more global type of analysis was used to check the individual industry projections and to provide an overall framework for the projections. The general approach followed in the development of this framework began with the population and labor force projections developed by the Bureau of the Census and the Bureau of Labor Statistics, respectively. Assumptions were made as to the size of the Armed Forces, the level of unemployment, annual hours of work, and output per man-hour. Multiple regressions were run which took into account past employment trends and relationships, and variables such as unemployment, size of the Armed Forces, Gross National Product, and population. By means of this technique, preliminary projections of manpower requirements were developed for each industry for which adequate historical data were available.

The results of the multiple regression analysis were then examined in light of the detailed industry analyses previously described, and further judgment decisions made as to the level of each industry's manpower requirements in the projected period. Discussions with representatives of industry and unions also provided essential background in making these judgments, as did analyses of trends and projections for the economy as a whole or for individual industries made by other groups, such as the National Planning Association, Stanford Research Institute, State and local government agencies, and universities. Other research currently being conducted in the Bureau of Labor Statistics by the interagency economic growth project and the Office of Productivity and Technological Developments also contributed to these final judgments.

The nature and significance of the projections included in this report reflect directly the method used. It is possible to posit a variety of patterns of economic growth for the United States, each consistent with an assumption of high levels of employment. The same total of employment might be attained, for example, by a variety of combinations of consumption expenditures, private investment, and government expenditures. For many purposes, it would be useful to explore the implications of alternative combinations for manpower requirements, and the Bureau of Labor Statistics is making such studies. The present projections reflect an economy in which the patterns of economic growth follow the broad trends of the postwar period, and in which relationships between such basic variables as consumption, investment and Government expenditures are most like those which have obtained in years when levels of employment were high, with allowance for long-term trends in these relationships. More specifically, the projections reflect a gross national product of about $1 trillion in 1975 (in 1964 dollars), with a somewhat more rapid growth in gross private domestic investment than in personal consumption expenditures or Government expenditures.

Methodology of Occupational Projections. The starting point in most of the studies of future occupational requirements was an analysis of the factors affecting the demand for workers in the occupation, and an assessment of how these factors might operate in the future. Occupational employment is affected by a host of factors. Technological change is most often discussed as the factor affecting occupational employment, but occupational changes are influenced by other factors, such as growth in population and its changing age distribution, government policies, institutional factors, or by the relative supply of workers in other occupations. Also influencing occupational employment are changes in the total demand for the product produced by the industry employing the workers, changes in the levels of income and distribution of income among consumers, industry and government, and changing patterns of consumption. (A more detailed discussion of these factors appears in Part IV.)

It is apparent, in view of this multitude of factors, that no one technique can be used successfully to project manpower requirements in all occupations, or, for that matter, in all industries. The growth and decline of each occupation is affected by its own complex of factors. The number of teachers required, for example, is affected by the number of pupils to be taught (which in turn is related to birth rates and trends in the proportion of children at each age who attend school) and by trends in the ratio of teachers to pupils, which depend upon educational practices and available financing.

Projections of requirements for engineers, as another example, require consideration of entirely different factors, such as the growing utilization of technical personnel, the increasing technological complexity of industrial products and processes, changes in the level and composition of expenditures for defense, and growing research and development activities. Requirements for automobile mechanics were related to the projected number of new automobiles and accessories and the age of existing automobiles; requirements for radio and TV repairmen, to the number of radios and TV's sold, and their age and complexity. Thus, the occupational projections which are presented in this report were based on an analysis of the specific factors most closely related to the demand for that occupation. However, they also took into account the overall framework of future industry manpower requirements.

Projections of occupational requirements were also developed through the use of the occupational-industry matrix program currently being developed in the Bureau. In the matrix program, occupational patterns for detailed industries were developed for a current year, projected to 1975, and then applied against the overall industry projection framework. The preliminary occupational projections resulting from the application of occupational patterns to industry totals were then analyzed and compared with the occupational projections developed independently. In general, the final projections presented in this report are based on judgment as to the affect of demand factors on specific occupations.

It should be noted that the projections in this report were developed without taking into account explicitly limitations in the future supply of personnel. Thus, they represent the Nation's requirements for workers in 1975 under the stated assumptions; they are not predictions of what employment actually will be in that year. Obviously, these industry and occupational requirements can be fulfilled only if an adequate supply of workers with the needed skills becomes available.

It should be noted also that the occupational and industry statements show only the net increase in manpower requirements anticipated by 1975.

No attempt has been made to include estimates of the number of workers who will be needed to fill job openings created by deaths, retirements, and transfers out of an occupation or industry. In many cases, more workers will be needed to fill positions left vacant because of deaths, retirements, and transfers than will be needed to staff new positions created by growth in requirements. Even in those industries or occupations in which manpower requirements are expected to decline in the years ahead, large numbers of workers will be needed as a result of attrition of experienced workers. In studies designed to estimate needs for education and training, the Bureau makes allowance for these factors.

Another point for readers to bear in mind is that the projections of requirements in 1975 are meant to apply only to the overall long-run period beginning in 1964 and ending in 1975. The reader is cautioned against interpolation between the 1964 and 1975 figures to derive estimates for any other year. Similarly, the use of the target year 1975 is not meant to imply that the projections of requirements will be realized in that year and that year only, and regardless of the cyclical conditions which prevail at that time. The projections are thus meant to apply to a year in the mid-1970's when the stated assumptions correctly describe the state of the economy.

PART II. PROJECTIONS OF INDUSTRY MANPOWER REQUIREMENTS IN 1975

As indicated in the introduction, the projections of manpower requirements developed in this report are based on a labor force of 94.1 million workers in 1975, and assume that the size of the Armed Forces will be 2.7 million in that year. Subtracting the Armed Forces from the total labor force results in a civilian labor force of 91.4 million workers. Utilizing the assumption of 3 percent unemployment in 1975 set down by the National Commission on Technology, Automation, and Economic Progress, total employment requirements in the United States in 1975 will be 88.7 million, an increase of 26 percent over the 70.4 million workers employed in 1964. This projected increase in requirements reflects both the expected growth in the labor force and the added rise in employment involved in reducing unemployment from the 5.2 percent level in 1964 to the assumed 3 percent level in 1975.

The following discussion describes anticipated future manpower requirements in the economy, including those in agriculture, and for self-employed workers, unpaid family workers and domestic workers, all of which are based on Census counts of people and the individual industry projections based on the Bureau of Labor Statistics counts of jobs for wage and salary workers. Part II also presents detailed statements on past employment trends and projected requirements for wage and salary workers in each one- and two-digit SIC industry in the economy, including a description of the factors affecting employment. A discussion of the impact of changing technology ends each statement. Part II concludes with a brief discussion of how broad industry groups are affected by general business conditions, as reflected in the level of unemployment in the economy as a whole.

Total Employment Requirements in 1975

Despite the overall increase of more than one-quarter in total manpower requirements, not all industries are expected to share equally, if at all, in this anticipated growth, and major changes in the industrial distribution of employment are expected by 1975. Manpower needs in agriculture are expected to continue to decline between 1964 and 1975, even under conditions of a generally full employment economy. Underlying the long-term decline in farm employment will be the continued rise in output per worker as a result of the increased use of machinery, fertilizers, feed additives, pesticides, and other technological advances. The continuing decrease in the number of farms—particularly the small, low-income-producing units—will also contribute to the decrease in the number of farmers. And further mechanization may result in a decrease in the number of hired farmworkers, despite the continuing increase in large farms. As a result, between 1964 and 1975, agricultural employment is projected to decline by more than one-fifth (21 percent), falling from 4.8 million in 1964 to 3.7 million in 1975—a significant decline but nonetheless a slowing of the rate of decline of the post-World War II period. (See table 1.) (A more detailed discussion of manpower requirements in agriculture appears later in Part II.)

In contrast to the decline in agricultural manpower needs, the projections for 1975 show a rise in total manpower needs in the nonfarm economy of nearly one-third (29 percent). By 1975, nonfarm manpower requirements are expected to increase by more than 19 million over the 65.6 million workers employed in 1964. Most of the increased nonfarm manpower needs will be in wage and salary employment, which is projected to rise at a slightly faster rate than total nonfarm employment. Requirements for nonfarm wage and salary workers are expected to rise from 56.1 million in 1964 to 73.4 million in 1975. The number of other workers (domestics and self-employed and unpaid family workers) is expected to increase over the 11-year period also, but at a somewhat slower rate. By 1975, the number of these workers needed may reach 11.5 million, a 21-percent increase over the 9.5 million employed in 1964.

Up to this point the overall figures on farm and nonfarm employment cited have been based on the monthly labor force surveys made by the Bureau of the Census for the Bureau of Labor Statistics and represent the total number of employees in the farm and nonfarm economy, including self-employed and unpaid family workers, as estimated from surveys of households. The discussions of individual industries which follow, however, are geared to the estimates of wage and salary employment derived by the Bureau of Labor Statistics from payroll reports and thus exclude these self-employed and unpaid family workers. In addition, the Bureau of Labor Statistics' data on wage and salary workers, which are derived from payroll reports of employers, represent the number of *jobs* in the nonfarm economy rather than the number of people, and thus count dual jobholders in each job they hold. Because of the differences in the way the data are collected, and because of these dual jobholders, the count of jobs from the establishment surveys of the Bureau of Labor Statistics has generally been 2 to 2.5 million higher than the count of people from the household surveys of the Bureau of the Census. Thus, in order to translate the projections of the overall number of people (based on household survey data) into the number of jobs (estimated from reports based on payrolls), it was necessary to make an assumption as to the difference between the count of jobs and the count of people in 1975. On the basis of this assumption, the derived projection of more than 73 million nonfarm wage and salary employees in 1975 was adjusted upward to 75.9 million nonfarm wage and salary jobs in 1975. The employment trends projected for each major industry division presented later are thus related to this projection of 75.9 million nonfarm wage and salary jobs in 1975. (For a discussion of the differences in composition and employment levels between the monthly labor force surveys and the Bureau of Labor Statistics' estimates of employees in nonfarm establishments, see the technical appendix in any current issue of the BLS periodical, *Employment and Earnings*.)

The sections which follow present the projections of manpower requirements in 1975 for each major industry division—agriculture;[2] mining; contract construction; manufacturing; transportation and public utilities; trade; finance, insurance, and real estate; services; and Government. Presented first is a summary of the overall set of projections, followed by a brief discussion of each of the major industry divisions, and a more comprehensive discussion of the two-digit SIC industries which comprise each major division.

Industry Manpower Requirements in 1975

The industry projections developed for this report indicate that the rate of job growth will continue to be higher in the service-producing industries than in the goods-producing industries. Employment in the goods-producing industries—manufacturing, construction and mining—rose 13 percent between 1947 and 1964, or from 18.5 million to 20.9 million. Significant gains in productivity resulting from automation and other technological developments have permitted large increases in output in the goods-producing industries without corresponding increases in employment.

Between 1964 and 1975, manpower requirements in the goods-producing sector (excluding agriculture) are expected to increase by about 17 percent to 24.6 million. The projected increase in manpower requirements in the construction industry (37 percent) contrasts with a slight decline in mining (of about 3 percent). Manpower requirements in manufacturing are expected to rise by about 14 percent, or at half the rate of increase for the economy as a whole. In agriculture (not included in the above discussion of the goods-producing industries), employment is expected to fall by about 21 percent.

Requirements in the service-producing industries—transportation and public utilities; trade; finance, insurance, and real estate; services and miscellaneous industries; and Government—are expected to continue the rapid increase of the post-World War II period, when the number of workers on the payrolls of these industries increased 46 percent, from 25.4 million in 1947 to 37.2 million in 1964.

TABLE 1. WAGE AND SALARY WORKERS, BY INDUSTRY GROUP, ACTUAL 1964 EMPLOYMENT AND PROJECTED 1975 REQUIREMENTS

Industry group	Actual 1964 employment		Projected 1975 requirements		Percent change, 1964–75
	Number	Percent	Number	Percent	
All industry groups	62,917	100.0	79,620	100.0	27
Agriculture [1]	4,761	7.6	3,745	4.7	21
Mining	633	1.0	620	.8	(2)
Contract construction	3,056	4.9	4,190	5.3	37
Manufacturing	17,259	27.4	19,740	24.8	14
Transportation and public utilities	3,947	6.3	4,425	5.6	12
Trade	12,132	19.3	16,150	20.3	33
Finance, insurance, and real estate	2,964	4.7	3,725	4.7	26
Services and miscellaneous	8,569	13.6	12,275	15.4	43
Government	9,595	15.3	14,750	18.5	54

[1] Includes self-employed and unpaid family workers.
[2] Less than 3 percent.

NOTE: Employment figures for 1964 are adjusted to the 1964 benchmark levels. Because of rounding, individual items may not equal totals. Projections assume a 3-percent level of unemployment in 1975.

Over the 1964–75 decade, manpower requirements in the service-producing industries are expected to increase by 38 percent, reaching 51.3 million in 1975. The largest increase in manpower requirements in the service-producing sector is expected to be in Government, nearly all in State and local government. Greater-than-average increases are also expected in the service and miscellaneous industries group (a growth of 43 percent), trade (33 percent), and finance, insurance, and real estate (26 percent). The number of jobs

[2] Although a brief description of future manpower requirements in agriculture appears earlier in Part II, a more detailed examination of future agricultural employment is also presented here in order to provide the reader with an overview of the entire economy.

in transportation and public utilities will show a relatively small increase by 1975.

The industrial composition of the economy will change significantly in the years ahead as a result of the differential rates of growth projected for industries. Government and the service and miscellaneous industries will increase sharply as a proportion of total industry employment. Other industries whose relative importance will increase are construction and trade. On the other hand, the relative importance of manufacturing and transportation and public utilities will decline slightly. Continued sharp declines in the proportion they represent of total requirements will take place in mining and in agriculture.

Employment trends projected for each major industry division are discussed in detail in the following sections.

Agriculture

Summary

Agricultural employment is expected to decrease by more than one-fifth between 1964 and 1975, despite an anticipated rise of approximately one-fifth in farm output. Technological change is expected to be a major factor in reducing the number of farm workers during this period.

Employment Trends

1947–64. Agricultural employment, including wage and salary, self-employed, and unpaid family workers, dropped from about 8¼ million in 1947 to less than 4.8 million in 1964, a reduction of 42 percent, despite a rapid rise in farm output over this period. Accompanying this contraction in employment was an even more precipitous decline in man-hours of work on farms, which shrunk from 17.2 million hours in 1947 to 8.4 million hours in 1964. Employment declined primarily because of increasing application of laborsaving technological innovations and the increasing average size of farms.

Self-employed farmers and unpaid family farm workers, who accounted for two-thirds of agricultural employment in 1964, declined by more than 50 percent over the 1947–64 period, while wage and salary workers declined by almost 6 percent.

Employment in agriculture is concentrated in a relatively few major types of farming. An estimated 6 of every 10 workers engaged in commercial farmwork were employed on livestock, dairy, cash grain, and cotton farms. The remaining workers on commercial farms were employed on farms producing vegetables, fruits and nuts, poultry, tobacco, miscellaneous farm products, and other farm commodities. Virtually all wage and salary workers were employed on commercial farms, and two-thirds of all self-employed farmers and unpaid family farmworkers were engaged in commercial farming activity.

Wide variations in the rate of employment decline by major farm activity are indicated by changes in man-hours of farm labor. For example, between 1947 and 1964, man-hours of labor used in the production of cotton declined by two-thirds, compared with a one-third decline in man-hours applied to tobacco production. The number of man-hours used in production of food and feed grains and livestock declined by two-thirds and two-fifths, respectively.

The major factor responsible for the decline in farm employment during the post-World War II period was the great increase in efficiency of farm operations, resulting from the increased use of power equipment and the widespread application of scientific farming techniques on increasingly larger farms. The average farm increased from about 197 acres in 1947 to 325 acres in 1963, and crop production per acre rose by about 40 percent between 1947 and 1964. Larger farms permitted more effective use of machines, equipment, and chemicals.

The horsepower of tractors used on farms increased by 168 percent between 1947 and 1964. In addition, the use of trucks, specialized planting and harvesting equipment, and electrically powered machines and equipment contributed significantly to farm efficiency.

The application of plant nutrients to the soil increased fourfold between 1947 and 1964. The use of pesticides, herbicides, and improved strains of crops also increased significantly. Improved animal and poultry feeds, the addition of vitamins and other food supplements, and use of antibiotics contributed to the improved quality and quantity of the food produced.

Largely as a result of the kinds of innovations described above, production per farm man-hour more than doubled between 1947 and 1964.

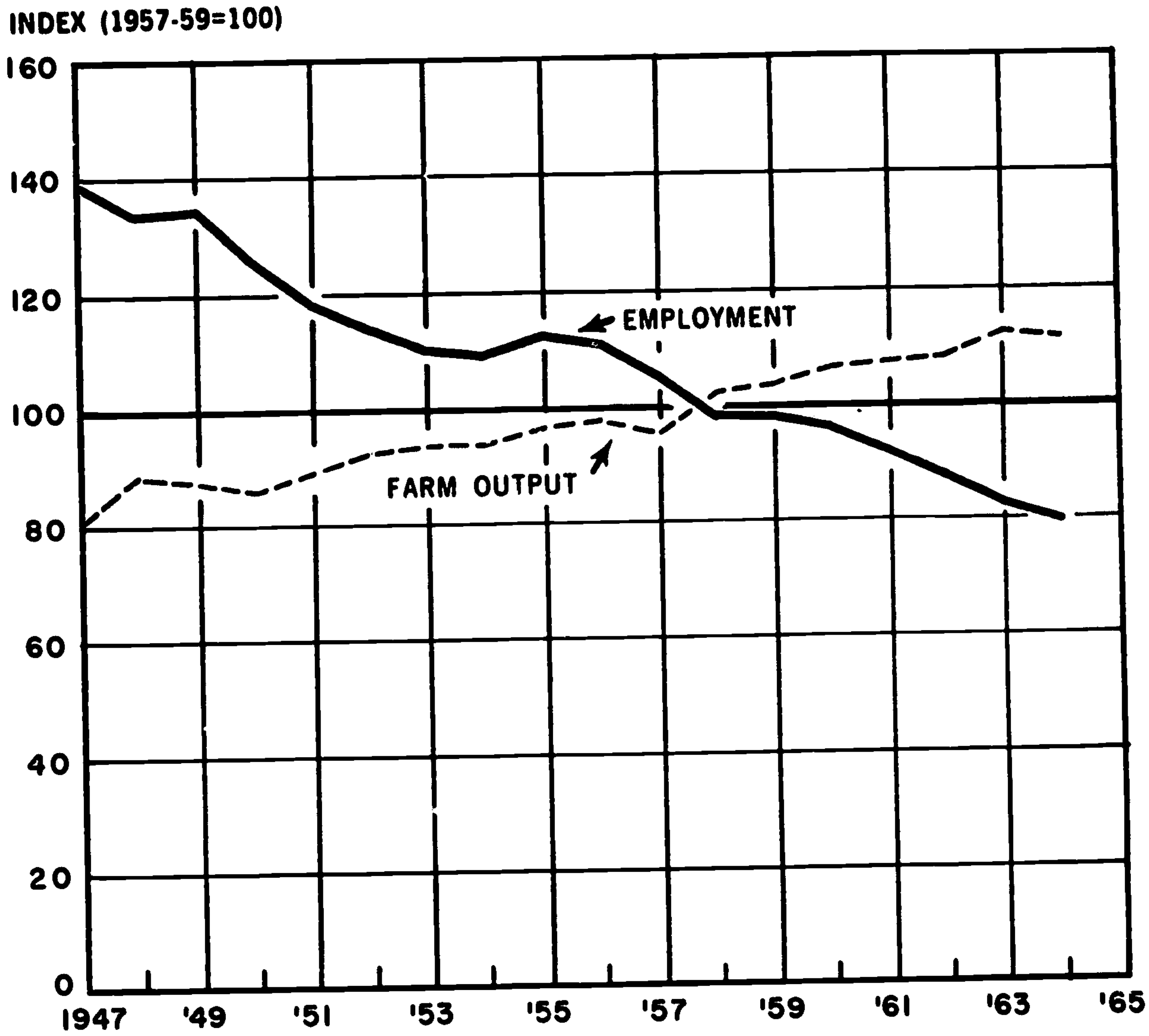
1964–75. Agricultural employment [3] is expected to continue to decline in the future—from about 4.8 million in 1964 to 3.7 million in 1975, despite a rise of about one-fifth in agricultural output. Demand for agricultural products will continue to increase primarily as a result of growing national and world population.

Employment in agriculture is expected to decline for reasons similar to those in the past. The use of electrical and mechanical power equipment will continue to reduce farm employment. The size of the average farm will continue to grow. The competitive advantages of large farms will force

[3] The concept of employment requirements is less relevant in discussing actual levels of employment in agriculture than in most other industries. Because so many farmers own their own farms and continue in farming even though their incomes are low and their contribution to agricultural production for the market negligible, real manpower requirements in agriculture have been well below the number actually engaged in this work. The projections of employment in agriculture in this report are, therefore, not estimates of the manpower required to produce the anticipated level of farm output in 1975, but are projections of the number of workers likely to be employed in agriculture.

EMPLOYMENT AND AGRICULTURAL PRODUCTION, 1947-64

Employment (in 000's)	
1947	8,256
1948	7,960
1949	8,017
1950	7,497
1951	7,048
1952	6,792
1953	6,555
1954	6,495
1955	6,718
1956	6,572
1957	6,222
1958	5,844
1959	5,836
1960	5,723
1961	5,463
1962	5,190
1963	4,946
1964	4,761



Sources: Employment, Bureau of Labor Statistics; agricultural production, U.S. Department of Agriculture.

many operators of less-efficient, small farms[4] to sell their holdings or divert them to other uses. The more efficient small farm operators will enlarge their farm holdings to take advantage of the economies of scale made possible through mechanization.

Probably the only type of agricultural workers that will increase in numbers in the future are those who perform activities such as cropdusting, fertilizing, or machine harvesting.[5]

Effects of Technological Developments on Future Employment

Technological developments are expected to have a significant effect on the number of workers engaged in farming during the 1964–75 period. New and improved electrically and mechanically powered machines and equipment will be introduced that should increase the optimum size of farms for many crops and for livestock production. Greater use of plant nutrients,[6] pesticides, and herbicides will permit greater output per acre on fewer acres in production. Use of improved animal feeds and improved methods of feeding will boost meat and poultry production per dollar of expenditure. Better strains of crops, including those less susceptible to damage by machine harvesting, and improved breeding of livestock also will increase farm output and efficiency. While the overall effect of these technological changes will reduce the number of farmworkers,

[4] According to the U.S. Department of Agriculture, sales of farm products on each of about 1.5 million farms produced income of less than $2,500 in 1964.

[5] According to the *Factbook of U.S. Agriculture* (U.S. Department of Agriculture, January, 1965), p. 47, nearly 400 thousand workers are engaged in such activities.

[6] Ibid., p. 36, states that "According to the 1959 Census of Agriculture, 42 percent of the harvested cropland was fertilized, compared with 37 percent in 1954. Future requirements for fertilizer will develop with increased population growth and education of the farmer in better use of fertilizer products. Only 11 percent of U.S. farmers used recommended rates (of fertilizer) in 1959 and 37 percent used none on their cash crops."

it will increase the need for workers with training in modern farming techniques.

Improvements will continue to be made in farm tractors and implements. Higher powered diesel units are gradually replacing gasoline powered units; "liquid-petroleum" gas units have also been introduced; and research is progressing on fuel-cell power. Some success has been achieved in the development of equipment for harvesting vegetable, fruit, and nut crops. Materials handling equipment is increasingly being used in conjunction with field machines, in processing and storage of crops, and in feeding animals. In some instances, automatic controls have been applied to this equipment. The broader application of automatic control technology to crop and livestock production is likely in the future.

We may expect to find greater use of electronic data processing equipment applied to a much wider range of farm activities in the future. It is reported that computers are already being used on some farms to handle accounting and cost control functions. Much more widespread use of this equipment is anticipated because it allows more efficient management of operations.

While machines and equipment lead to immediate improvements in farm operation efficiency, the care of cropland and grazing land determines the longrun success of the farmer. Continued improvements are expected in soil nutrients, control of insect pests and unwanted vegetation, water control, and the prevention of erosion—all important aspects of this care.

Technological developments are expected to continue to change the knowledge and skills required of farmers and farmworkers. Crop, animal, and fowl production is expected to become more specialized in the future. The farmer will be faced with increasingly complex decisions in finance, equipment purchase, soil conservation, crop and livestock selection and degrees of specialization, and manpower requirements. His employees will no longer be hired only because of their physical abilities, but because of their technical knowledge and other skills.

Mining (SIC Division B)

Summary

Employment requirements in mining are not expected to change much between 1964 and 1975, compared with a decrease of about one-third between 1947 and 1964. Technological change is expected to continue to be a factor in reducing employment requirements in mining.

Employment Trends

1947–64. In 1947, 955,000 workers were employed in mining; by 1964, employment had fallen to 633,000.

More than two-fifths (about 45 percent) of total employment in mining in 1964 was in the crude petroleum and natural gas major industry group. Coal mining accounted for nearly one-fourth (about 23 percent) of total mining employment and most coal mining workers were in bituminous mining. The remaining mining workers were employed in quarrying and mining of nonmetallic minerals, except fuels, (about 19 percent) and metal mining (about 13 percent).

Employment in mining declined between 1947 and 1964, despite an increase in mining output. Only coal mining experienced a decline in both employment and output. Technological innovations that raised output per worker in coal mining were particularly significant because they were introduced at a time when the industry's total output was declining. In two major industry groups—crude petroleum and natural gas, and mining and quarrying of nonmetallic minerals—employment increased between 1947 and 1964.

1964–75. Manpower requirements in mining are expected to be about 620,000 in 1975, not much different than in 1964, despite an anticipated substantial increase in mining output.

Employment trends for the major industry groups within mining are expected to differ substantially because of differences in levels of demand and the impact of technological developments. For example, worker requirements in the mining and quarrying of nonmetallic minerals, except fuels, are expected to increase rapidly primarily because of the anticipated increase in construction materials, particularly for highway construction. A slight increase in labor requirements is expected in metal mining as the demand for ores is stimulated by growing expenditures for consumer products, rising capital equipment expenditures, and a continued high level of defense spending.

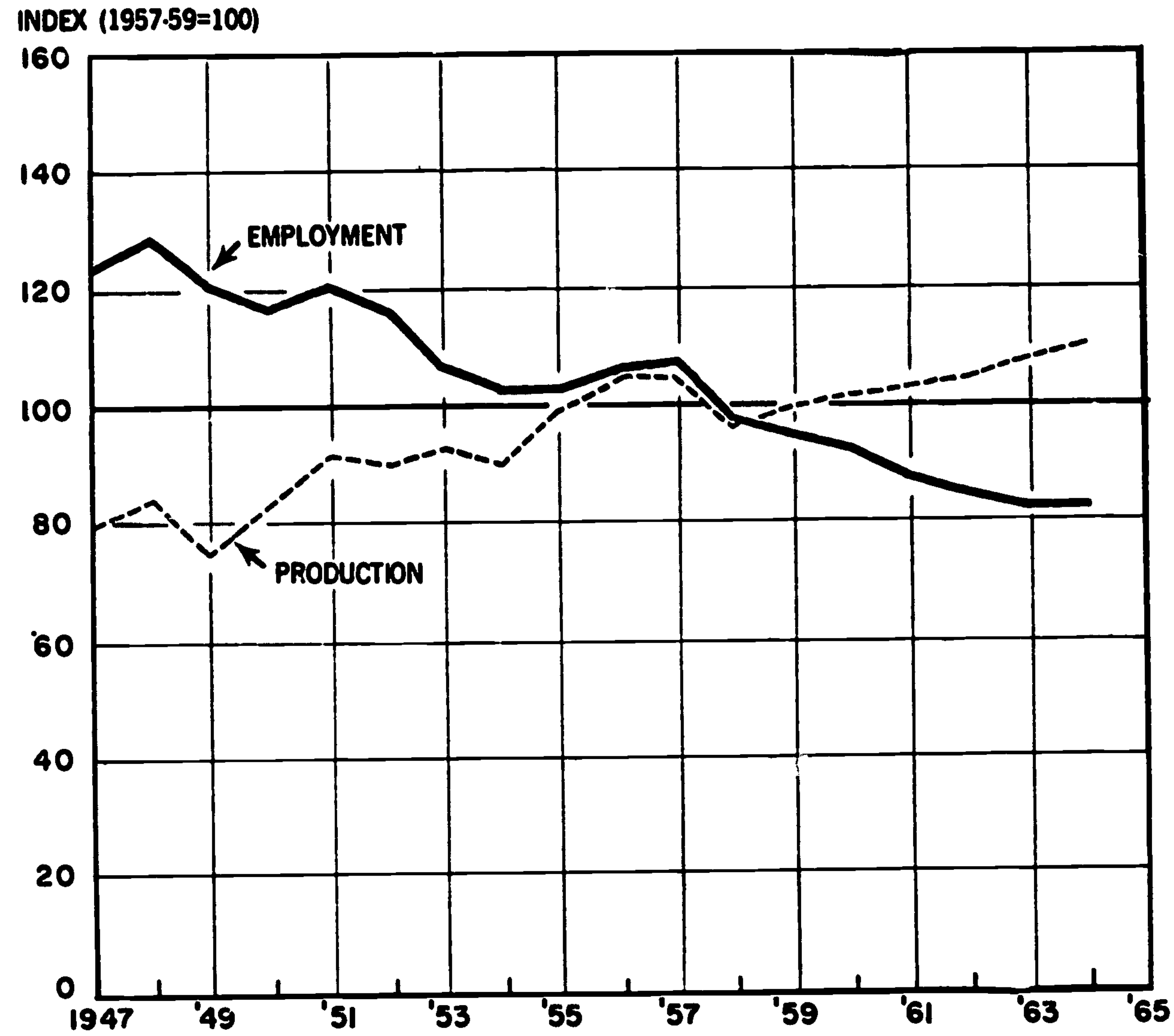
In contrast, manpower requirements in coal mining are expected to decline, although at a slower rate than in the past, and requirements in crude petroleum and natural gas establishments are likely to remain relatively stable, despite rising demand for the products of these industries. Demand for coal will be stimulated by the growing need for fuels for industrial processing and power. In addition, the competitive position of coal is likely to improve through the industry's use of unitized trains, new and improved slurry pipelines, and other modern means of mass transport to move coal more cheaply.

Effects of Technological Developments on Future Employment

Technological developments are expected to have a significant effect on the number and characteristics of jobs in mining through the mid-1970's. In the crude oil and natural gas industry group, for example, production is increasingly being automated by means of "lease automatic custody transfer" (LACT) systems. LACT systems automatically pump, sample, monitor, and transfer the crude oil directly from wells through treating facilities to transmission pipelines for shipment to refineries. The greater use of LACT systems in the future will reduce demand for stationary engineers (pumpers), as well as for mine operatives and laborers, including workers who gage and switch oil tanks. On the other hand, requirements are expected to increase for foremen to supervise workers using LACT systems and for skilled mechanics to maintain and repair them. Also, the use of other, more efficient, exploration and recovery techniques in crude oil and natural gas extraction will affect manpower requirements. For example, the use of electrical, gravimetric, magnetic, and seismic discovery techniques, and advances in deep well and underwater drilling techniques, should increase requirements for scientists, such as geophysicists, engineers, and other workers skilled in the use, operation, and maintenance of increasingly complex equipment. On the other hand, future requirements for mine operatives, such as roustabouts and

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN MINING, 1947-64

Employment (in 000's)	
1947	955
1948	994
1949	930
1950	901
1951	929
1952	898
1953	866
1954	791
1955	792
1956	822
1957	828
1958	751
1959	732
1960	712
1961	672
1962	650
1963	635
1964	633



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

roughnecks, who perform unskilled duties in drilling operations, may be reduced somewhat as drilling operations become more automated. Future increases in drilling activities may result in growing demand for workers in specific occupations, such as rotary drillers, but overall employment requirements for production workers are not expected to increase significantly.

Techniques for mining solid minerals in both surface (strip) and underground mines have improved steadily. In surface mining, major improvements include the use of more efficient blasting agents, power shovels, and drilling equipment. To move the materials mined, off-highway trucks with capacities to 100 tons or more are being used increasingly. In underground mining, recently developed continuous mining machinery systems can tear coal loose, load it on conveyors or shuttle cars, or dump it behind to be picked up by loading machines. An even more recent development is longwall mining with self-advancing roof supports. In this technique, coal is cut from a face 300 to 1,000 feet (as compared with 9 to 300 feet in short wall mining), as hydraulically powered roof supports advance behind an automatic cutter. Tunnel maintenance is reduced when this mining technique is used. The application of these and other technological developments is expected to accelerate in the near future, resulting in decreasing requirements for mine operatives and laborers, but increasing requirements for skilled mechanics. Similarly, underground metal mining is increasingly using equipment for automatic hoisting of ore, rubber tired ore transporters and mobile drills, and blasting materials that are pneumatically loaded into blast holes rather than "stick" explosives. Mine operators are achieving greater flexibility through the use of diesel equipment in place of electric trolley and air-powered machines.

Computers are being utilized in the mining industry increasingly. In metal mining, for example, periodic evaluation and review techniques (PERT) are being used by several companies in planning and controlling their operations. In the crude oil and natural gas sector, computers are being introduced for analytical and control purposes in exploration, extraction, and distribution operations. The use of computers is expected to increase as mines improve the efficiency of their operating procedures, resulting in some additional requirements for scientists, engineers, and programing specialists. On the other hand, increased use of computer systems to monitor and control production processes should decrease requirements for mine operatives.

Despite the generally adverse effects of recent technological changes on employment in the mining industry, some future changes may increase employment. For example, new benefication techniques have been developed that make the mining of low grade mineral deposits economical. One outstanding example of such a process makes possible the concentration of low grade ore such as taconite (which contains only 25 to 30 percent iron) into high grade ore with 60 percent or more iron content. Continued improvement of benefication techniques can be expected to increase requirements for all types of mine workers as the demand for beneficated ores increases. Demand for workers such as chemists, metallurgists, engineers, and technicians should increase because of the complexities of these techniques. In crude oil and natural gas extraction, technological changes should increase requirements for craftsmen and mine operatives skilled in offshore drilling and other relatively new recovery techniques. Thermal methods are expected to be used increasingly for secondary recovery in older fields and primary recovery where crude oils are too heavy to be produced by conventional methods. Also, improvements in offshore drilling technology should increase underwater oil recovery activities.

Contract Construction (SIC Division C)

Summary

Employment requirements in the contract construction division are expected to increase by more than one-third between 1964 and 1975, because of a rapid rise in construction activity. This is a slightly faster rate of employment growth than prevailed over the 1947–64 period. Labor requirements will not increase as fast as construction activity in the decade ahead because output per worker will continue to increase.

Employment Trends

1947–64. Employment in the contract construction division increased from nearly 2 million to more than 3 million between 1947 and 1964. Employment reached nearly 3 million in 1956, but fluctuated downward to slightly more than 2.8 million in 1961, mainly because of a slowdown in activity and the increasing use of laborsaving technological innovations. Between 1961 and 1964, employment and new construction activity increased steadily.

In 1964, almost half of the workers in the contract construction division were employed by special trades contractors; slightly more than thirty percent were employed by building construction general contractors; and the remainder worked for heavy construction general contractors.

Rates of employment growth differed widely among the three contract construction major industry groups between 1947 and 1964. Employment increased very rapidly (about 74 percent) in the special trades contractors major industry group, mainly because of the increasing importance of electrical, plumbing, air conditioning, and other work usually performed by special trades contractors. Rapid employment growth (about 68 percent) in the heavy construction contractors major industry group was spurred by a fourfold increase in highway construction (in constant dollar terms), as well as increases in the construction of sewer and water systems, airports, bridges, dams, and similar projects. Employment by building construction general contractors also increased substantially (about 26 percent). Employment in this major industry group rose to more than a million in 1956; by 1964, however, employment was 11 percent lower than in 1956, reflecting, in part, a slowdown in the rate of increase in residential construction activity.

1964–75. Employment requirements in the contract construction division are expected to rise by more than one-third between 1964 and 1975, to more than 4 million. Construction activity is expected to be stimulated by rising population and household formations, higher levels of personal and corporate income, a continued shift of the population from the cities to the suburbs, increases in government expenditures for highways and schools, and rising expenditures for new industrial and commercial facilities.

Employment requirements are expected to rise in all three major industry groups in the contract construction division; however, they are expected to increase faster among heavy construction contractors than among general and special trades contractors. A growing volume of highway construction generated by the Federal Government's long-range highway development program is expected to be an important factor in stimulating employment in this major industry group. Employment requirements of special trades contractors are also expected to increase rapidly, primarily because of the trend toward multibathroom homes; air-conditioned homes and other buildings; and more extensive wiring systems required by the growing use of electrical appliances and machinery. A moderate to rapid increase in employment requirements is expected among general building contractors, mainly because of the expected increase in residential building spurred by a high rate of family formation.

Effects of Future Technological Developments on Employment

Technological developments are expected to have a significant effect on both the number and characteristics of contract construction jobs. For example, increases in the size, capacity, speed, and mobility of construction machinery will decrease unit labor requirements for operators. Mobile truck cranes now in use can lift 125 tons to a height of 330 feet (equivalent to a 33-story building). These cranes can travel over highways at speeds up to 35 m.p.h. Other equipment being used increasingly includes trucks that haul 100 tons of dirt, scrapers that pick up and carry 75 to 150 tons of dirt, and bulldozers with 1,000 horsepower engines. The improved design and durability of equipment, including machinery compo-

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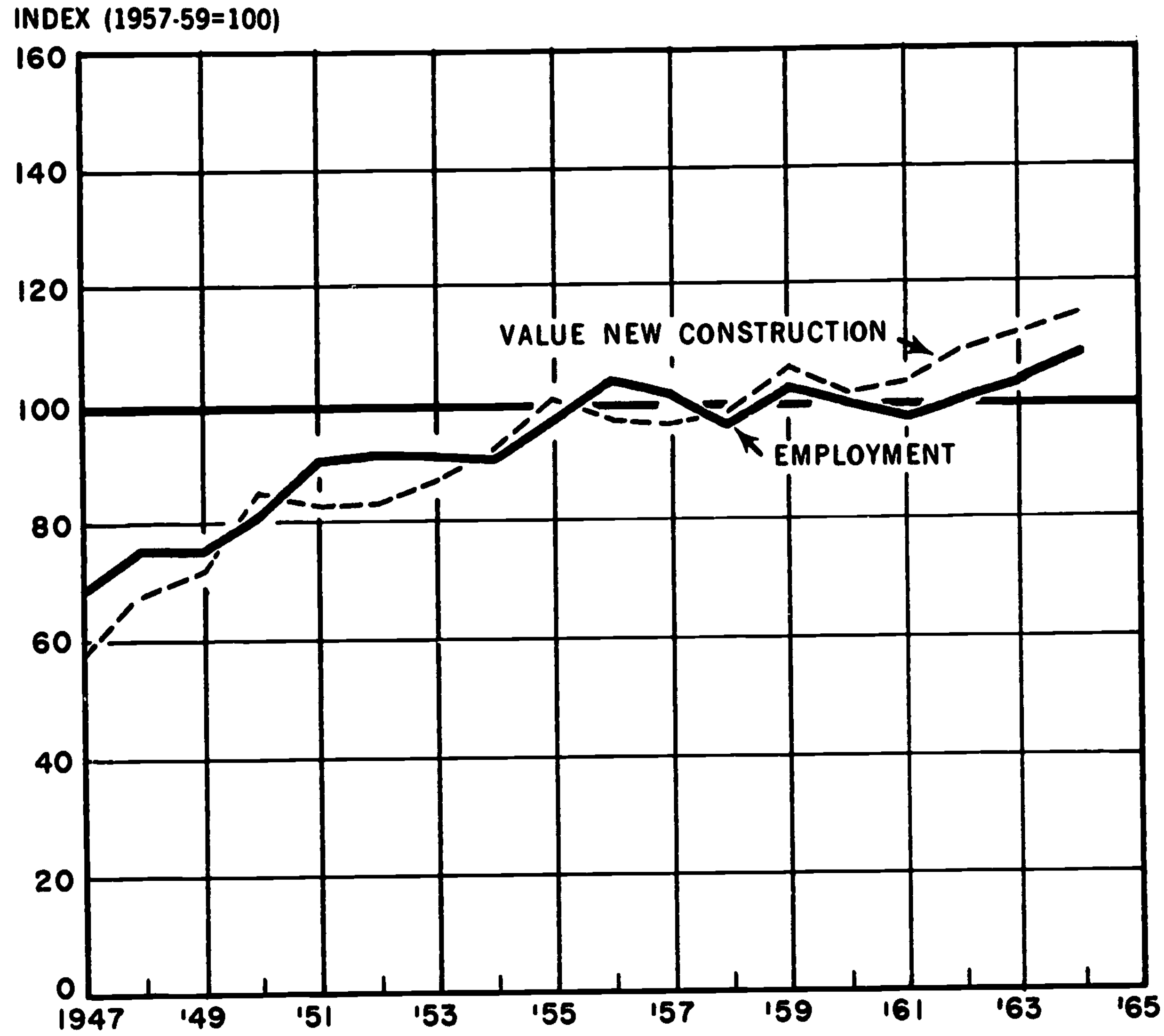
EMPLOYMENT IN CONTRACT CONSTRUCTION AND VALUE OF NEW CONSTRUCTION,[1] 1947-64

Employment (in 000's)	
1947	1,982
1948	2,169
1949	2,165
1950	2,333
1951	2,603
1952	2,634
1953	2,623
1954	2,612
1955	2,802
1956	2,999
1957	2,923
1958	2,778
1959	2,960
1960	2,885
1961	2,816
1962	2,902
1963	2,963
1964	3,056



Source: Employment, Bureau of Labor Statistics; value of new construction, Business and Defense Services Administration.

[1] Data for new construction put in place are not directly comparable with the employment data, because maintenance and repair expenditures are not included. However, new construction put in place reasonably reflects trends in construction activity.

nents, has improved maintenance efficiency. Many of the new machines are equipped with power steering, power transmissions, rubber tires, and electronic and hydraulic controls that make them easier to handle, more maneuverable, and faster than the older equipment. In addition, new types of machines are being developed constantly. For example, a recently introduced concrete paving machine spreads, vibrates, forms, and finishes concrete paving in one continuous operation, replacing at least four conventional machines used in concrete paving. Other machines are being introduced that are designed especially for use on small construction projects.

Less spectacular, but very significant, improvements are continually being made in handtools and other construction equipment that increase the efficiency of construction work. Handtools that are expected to be used increasingly include cordless electric drills, high-speed nailing machines, and a power tool that can nail and drill in the same operation. Tools and equipment now being used by the electrician include multiple spindle drills, more efficient conduit benders, and "kits" of splicing material that have reduced the time needed to do field insulation of cable splices. New and improved powered equipment used by the cement finisher include portable, powered screeds; electric concrete vibrators; hydraulic joint forming machines; powered concrete cutting saws; and cement finishing machines. Improved bricklaying machines have been introduced in recent years and, if their use becomes widespread, they could slow the growth of requirements for bricklayers. Plastering machines and spray paint equipment have decreased the amount of time necessary to perform some plastering and painting operations.

Material handling techniques on construction projects are fast becoming mechanized. Items formerly unloaded and carried to the construction site by hand, such as concrete and brick, are now being moved by forklift trucks, motorized wheelbarrows, and conveyor belts, and lifted to the upper floors of multistoried buildings by cranes and high-speed mechanical hoists. The more widespread use of mechanical material handling equipment will reduce requirements for construction laborers employed to do materials handling work.

The growing use of building components prepared off the construction site is expected to improve the efficiency of onsite operations. Often the prefabricated components are manufactured in factories using assembly lines techniques, but in some cases they are prepared by the construction contractor in his shop or in fabrication shops near the job site. The prefabricated components can usually be installed as a complete unit. For instance, factory wired switchboards, control panels, raceways and "packaged" (preassembled and prewired) ceiling units eliminate the need for much onsite electrical wiring; thus, adversely affecting requirements for electricians. Growth in employment requirements for carpenters is expected to be limited by the growing use of floors, partitions, stairs, and roof trusses designed for easy and speedy installation. Preassembled plumbing "trees" are reducing the time needed for onsite plumbing. An important extension of prefabrication is "module building" in which units, including complete rooms and buildings, are available in standard sizes. The standardization of building components will contribute to their greater use.

A growing use of new and improved construction materials is expected to increase construction put in place per construction worker. Plastics are being used increasingly for a growing variety of components including partitions, wall panels, siding, insulation, roofing, and electrical and plumbing devices. Carpenters, plumbers, electricians, roofers, and painters are among the crafts that may be adversely affected by increasing use of plastic products. Wood products are increasingly expected to come from the factory with a prime coat and even a final coat, reducing the need for onsite painting. Improved paints, which last twice as long as conventional paints, also are expected to limit the need for painters. Other new materials expected to be used increasingly include adhesives that eliminate the need for conventional fasteners, nails with improved holding properties, and lightweight plasters with excellent soundproofing, acoustical and fireproofing qualities.

New construction methods will also increase worker efficiency on construction projects. More economical scheduling of operations and earlier completion dates result from the use of computers in work planning. Lift-slab construction techniques allow concrete floors to be poured at ground level and raised into place with synchronized hydraulic jacks. Walls can be processed in the same manner and tilted into place. Curtain wall techniques permit faster construction of buildings. Tower and climbing cranes increase efficiency in construction of multistoried buildings. New construction methods will affect the occupational composition as well as the number of workers in the contract construction division. For instance, curtain wall techniques tend to shift employment from carpenters and bricklayers to ornamental-iron workers; and the use of prestressed concrete in the place of steel beams tends to shift work from the structural-metal worker to cement masons and other workers.

Manufacturing (SIC Division D)

Summary

Employment requirements in manufacturing are expected to be about 14 percent higher in 1975 than the 17.3 million workers employed in 1964. The rate of growth implied by the projection will be somewhat faster than that during the 1947–64 period, as rapidly rising levels of manufacturing production are expected to more than offset significant increases in output per worker.

Employment Trends

1947–64. Between 1947 and 1964, manufacturing production more than doubled while employment increased less than 11 percent. The major factors responsible for growing demand for manufactures were continued growth of the population, rising personal and corporate incomes, an increasing number of households, and rising business activity. Laborsaving technological innovations, more efficient management, better trained workers, changes in occupational composition, and a variety of other factors increased output per worker and allowed much of the growing demand for manufactured goods to be met without commensurate increases in employment.

Although manufacturing employment was higher in 1964 than in 1947, employment did not grow consistently upward. Employment increased from 15.5 million in 1947 to 17.5 million in 1953, a period of high economic activity resulting from high demand for durable consumer goods and new plant equipment; large Federal expenditures for military items; and favorable balances in export trade. Between 1954 and 1964, manufacturing employment fluctuated with general business activity, but always below the 1953 level—falling as low as 15.9 million in 1958 and rising as high as 17.2 million in 1956 and 1957. In 1964, employment in manufacturing reached 17.3 million, surpassed only by 1953 and 2 wartime years—1943 and 1944. (Manufacturing employment reached an alltime high in 1965, almost 18 million workers.)

There are two general classes of manufacturing industries—those producing durable goods such as machinery, furniture, and automobiles, and those producing nondurable goods such as food, tobacco, and apparel. The following tabulation lists the major manufacturing industries and the proportion of total manufacturing employment accounted for by each in 1964.

	Percent of total manufacturing employment
Durable goods industries	(56.9)
Machinery, except electrical	9.3
Transportation equipment	9.3
Electrical machinery, equipment and supplies	9.0
Primary metals industries	7.1
Fabricated metal products	6.9
Lumber and wood products	3.5
Stone, clay, and glass products	3.5
Furniture and fixtures	2.4
Miscellaneous manufacturing industries (jewelry, toys, etc.)	2.3
Instruments and allied products	2.1
Ordnance and accessories	1.4
Nondurable goods industries	(43.1)
Food and kindred products	10.1
Apparel and related products	7.5
Printing and publishing	5.5
Textile mill products	5.2
Chemicals and allied products	5.1
Paper and allied products	3.6
Rubber and miscellaneous plastic products	2.5
Leather and leather products	2.0
Petroleum refining and related products	1.1
Tobacco	.5

Between 1947 and 1964, employment in the durable goods manufacturing industries increased 17 percent and in the nondurable industries by 4 percent, as production increased about 108 percent in durables and 97 percent in nondurables,[7] indicating a somewhat faster increase in output per worker in nondurable than in durable industries.

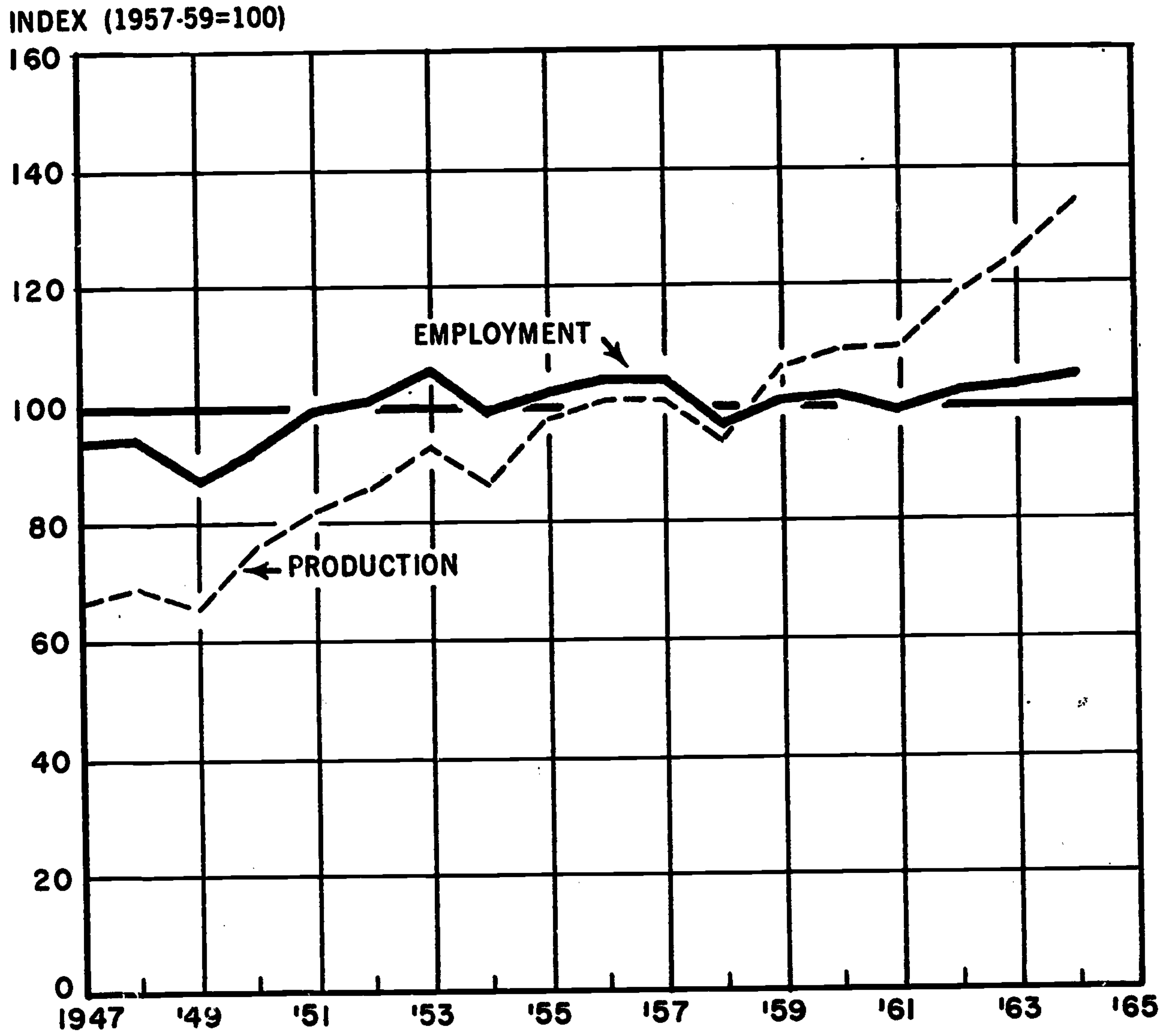
Changes in employment among individual manufacturing industries varied widely between 1947 and 1964, mainly reflecting changes in demand for the industries' products, in Government policy, in research and development activity, in imports and exports, technological developments, and other factors. For example, employment in the ordnance and accessories industry increased by over 800 percent during the 1947–64 period as demand for military items for the Korean conflict and later concern over defense capabilities and the race for intercontinental missile supremacy stimulated production. The complex items manufactured by this industry required considerable hand labor; in addition, rapid obsolescence of many items limited the application of mass production techniques in their manufacture. Similarly, segments of the electrical equipment industry that fabricated complex electronic items for sophisticated military-space products were unable to introduce many mass production techniques for the same reason.

Nevertheless, employment increased in some industries despite the existence of mass production techniques. For example, in the chemical and

[7] Based on Federal Reserve Board production indexes.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN MANUFACTURING, 1947-64

Employment (in 000's)	
1947	15,545
1948	15,582
1949	14,441
1950	15,241
1951	16,393
1952	16,632
1953	17,549
1954	16,314
1955	16,882
1956	17,243
1957	17,174
1958	15,945
1959	16,675
1960	16,796
1961	16,326
1962	16,853
1963	16,995
1964	17,259



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

allied products industry, which has utilized continuous flow process technology for years, rapidly increasingly demand for chemical products caused production to grow faster than output per worker. On the other hand, employment declined in industries such as petroleum refining, tobacco manufactures, and lumber and wood products as technological laborsaving innovations increased output per worker faster than production. The data in the following tabulation show the wide range of employment changes in the 21 major manufacturing industry groups.

	Percent change
Total manufacturing	11.0
Ordnance and accessories	815.2
Electrical machinery, equipment, and supplies	49.6
Instruments and allied products	38.3
Chemicals and allied products	35.2
Paper and allied products	34.4
Rubber and miscellaneous plastic products	34.2
Printing and publishing	31.8
Transportation equipment	25.9
Furniture and fixtures	20.8
Fabricated metal products	20.1
Machinery, except electrical	16.8
Stone, clay, and glass products	13.9
Apparel and related products	12.8
Food and kindred products	−3.0
Primary metals industries	−3.7
Miscellaneous manufacturing industries	−5.3
Leather and leather products	−15.4
Petroleum refining and related industries	−17.3
Tobacco manufacturing	−24.5
Lumber and wood products	−28.7
Textile mill products	−31.4

1964–75. Manufacturing employment requirements are expected to increase moderately through the mid-1970's, somewhat slower than total employment. By 1975, employment in manufacturing is projected to nearly 20 million, more than 14 percent above the 1964 level—an annual rate of increase of 1.3 percent compared with 0.6 percent between 1947 and 1964. During the next decade, production is expected to increase rapidly as the result of increasing household formations and rising business activity.

In general, manpower requirements are expected to continue to increase faster in the durable goods industries than in the nondurable industries, mainly as a result of greater increases in production and slower increases in output per employee in the durable goods sector.

As in the past, changes in employment in individual manufacturing industries are expected to vary widely, depending primarily on rates of change in production and the impact of technological change. (See appendix table A–2, p. 179, for projected employment requirements by industry between 1964 and 1975.)

Effects of Technological Developments on Future Employment

The increasing application of technological innovations to manufacturing processes is expected to continue to reduce unit labor requirements in manufacturing.

All manufacturing industries will not be affected equally by technological change. For example, in some industries such changes may reduce employment growth by increasing output per employee faster than production. On the other hand, technological changes in other industries may create new products and markets and increase production and employment. In nearly all industries, technological changes are expected to affect occupational patterns. For example, requirements should increase for skilled maintenance and repair workers to insure the operation of complex equipment and requirements for machine tenders and materials handlers should fall.

Most of the technological developments that are expected to affect employment in manufacturing can be included in seven broad categories: Numerical controls; new metal processing methods; machinery improvements; improved materials handling (including layout); new and improved raw materials and products; instrumentation and automatic controls; and electronic computers.

In the metalworking industries, more automatic production is being achieved through numerical control. This innovation provides a means of automatically controlling the operation of machine tools and certain other types of equipment by means of numerically coded information recorded in advance on punched cards, magnetic tape, or punched paper tape. Numerical control already is finding numerous applications in drafting, welding, and wiring operations. Expanding use of these techniques will be an important development in nearly all the metalworking industries, but will have very limited use in the nondurable industries.

New developments in metal processing, such as the basic oxygen process, will continue to reduce unit labor requirements and alter occupational patterns in primary metals establishments.

Improvements in machinery will continue to contribute to increased output per employee throughout manufacturing. New and improved models of automatic machinery, such as that used for stamping, pressing, bottling, packaging, or printing will continue to be introduced. Improvements in standard machinery will continue to be made by incorporating more powerful motors, heavier frames, simpler controls, and variable motor speeds.

Another important development in machine design is the trend toward the integration of hitherto separate machine operations into one large machine complex that carries through a series of operations with a minimum of intervention on the part of the machine tender. Many automatic transfer lines have been built that integrate materials handling equipment with a series of machine tools. Such transfer lines are applicable to the mass production of a variety of products requiring metalworking operations, including components for automobiles, appliances, farm equipment, and office machinery. Machines that perform automatic assembly operations are also being introduced, although at the moment the number of manufacturers that can justify using automatic assembly machines are comparatively few (generally large firms in the fabricated metal products, electrical and nonelectrical machinery, and transportation equipment industries). However, such machines are expected to be used increasingly in the years ahead and could have adverse effects on the requirements for assemblers in some industries.

Increasing mechanization is also occurring in the movement of materials, from receipt of raw materials to the shipping of final products. More powerful and maneuverable models of forklift trucks, hoists, cranes, conveyors, and tractors are being introduced in many industries including pulp and paper manufacturing, food processing, footwear manufacturing, meat packing, and foundries. For example, in the food and footwear industries, improved conveyors and other materials handling equipment are being used to move final products from the production line to the warehouse to the shipping platform.

Pneumatic conveyors are increasingly being used for moving granular materials. This technique is widely applicable in baking and in the manufacture of cement, flour, and fertilizer. The expanding use of improved materials handling equipment will primarily affect requirements for unskilled labor. These workers will most probably be replaced by relatively smaller numbers of semiskilled workers to operate or monitor equipment.

The development of new products is also expected to affect manpower requirements in many manufacturing industries. New products may create new markets and thus additional employment requirements, shift employment from one industry to another, modify occupational patterns, or decrease unit labor requirements. For exampl new synthetic fibers that require fewer mill operations than natural textile mill products may reduce unit labor requirements. Plastic materials, which are readily adaptable to mechanical processing, are replacing metal and wood; therefore resulting in an employment shift.

In many manufacturing industries, increasing use is being made of measuring and control instruments and electronic computers to increase the efficiency of continuous flow production processes. In the food industry, computers and sensors are being used to control the preparation of food and other automatic equipment is increasingly being used to grade, weigh, and package food items. In textile mills, electronic monitoring systems and photoelectronic devices are increasingly being used for quality control and inspection. The use of electronic controls, such as magnetic flowmeters, is expanding in the paper industry in connection with the industry's increased emphasis on automatic quality control. The potential of computers seems especially significant in the continuous process industries, such as paper and chemicals, and their use is spreading into others such as primary metals. In the chemical industry, computers are being used to direct and control entire production processes including automatic testing and analysis to insure optimum quality control. In pulp and paper, they may increasingly be used in connection with paper machines to accelerate grade changes and prevent breaks in the web, while providing optimum use of input materials and greater machine productivity.

The increasing use of instrumentation and computers in manufacturing will have several effects on the numbers and types of workers employed. Employment requirements for maintenance, technical, and supervisory workers will increase and requirements for production workers should decline.

Additional information of likely effects of technological change in manufacturing industries is included in the individual statements that follow.

Ordnance and Accessories (SIC 19)

Summary

Employment requirements in the ordnance and accessories major industry group are expected to remain at about the 1964 level of 247,000 workers through 1975, assuming an international situation in 1975 similar to that existing in 1964. In terms of employment, labor saving technological developments are expected approximately to offset slightly higher levels of production.

Employment Trends

1947–64. Ordnance employment is highly responsive to changes in defense spending and since World War II has fluctuated between 26,000 and 266,000 workers. Employment grew most rapidly during the Korean Conflict, rising from 30,000 in 1950 to about 234,000 in 1953. With the cessation of these hostilities, employment declined, but never below the pre-Korean level. With the increasing importance of missile production toward the end of the 1950's employment rose surpassing the Korean high of 234,000 workers by 1961.

In 1964, about three-fourths of ordnance workers were employed in establishments manufacturing ammunition, except small arms. Ninety percent of these workers were engaged in the production of guided missiles and spacecraft. Slightly less than one-fifth of all ordnance workers were in establishments making guns, howitzers, mortars, and related equipment; tanks and tank components; small firearms and small arms ammunitions; and other ordnance and accessories. The remaining workers were employed in establishments producing sighting and fire control equipment such as bomb sights, gun data computers, windage instruments, aiming directors, and sound locators.

Between 1958 and 1964[8] employment changes among the individual groups differed widely. Employment tripled in establishments assembling missiles and spacecraft and in firms producing, loading, and assembling ammunition over 30 mm. Employment also increased by nearly one-sixth in establishments producing guns, mortars, tanks and tank components, small arms, and small arms ammunition. Most of this growth was due to the increased emphasis on missile and space vehicle development, the changing kinds of materials required for fighting a "limited war," and the replenishment of inventories. Employment declined by almost two-thirds in establishments engaged in manufacturing sighting and fire control equipment due to the increased use of electronic equipment, such as computers and radar instruments, that is produced in other industries.

1964–75. Employment requirements in the ordnance and accessories major industry group are expected to remain at about the 1964 level of 247,000 workers through 1975. (It is assumed that major military assistance programs such as the one currently being provided to Vietnam will not

[8] BLS employment (payroll) data for individual ordnance industry groups are not available for the years prior to 1958.

be necessary in 1975.) Labor saving technological developments are expected to roughly offset slightly higher levels of production.

Effects of Technological Developments on Future Employment

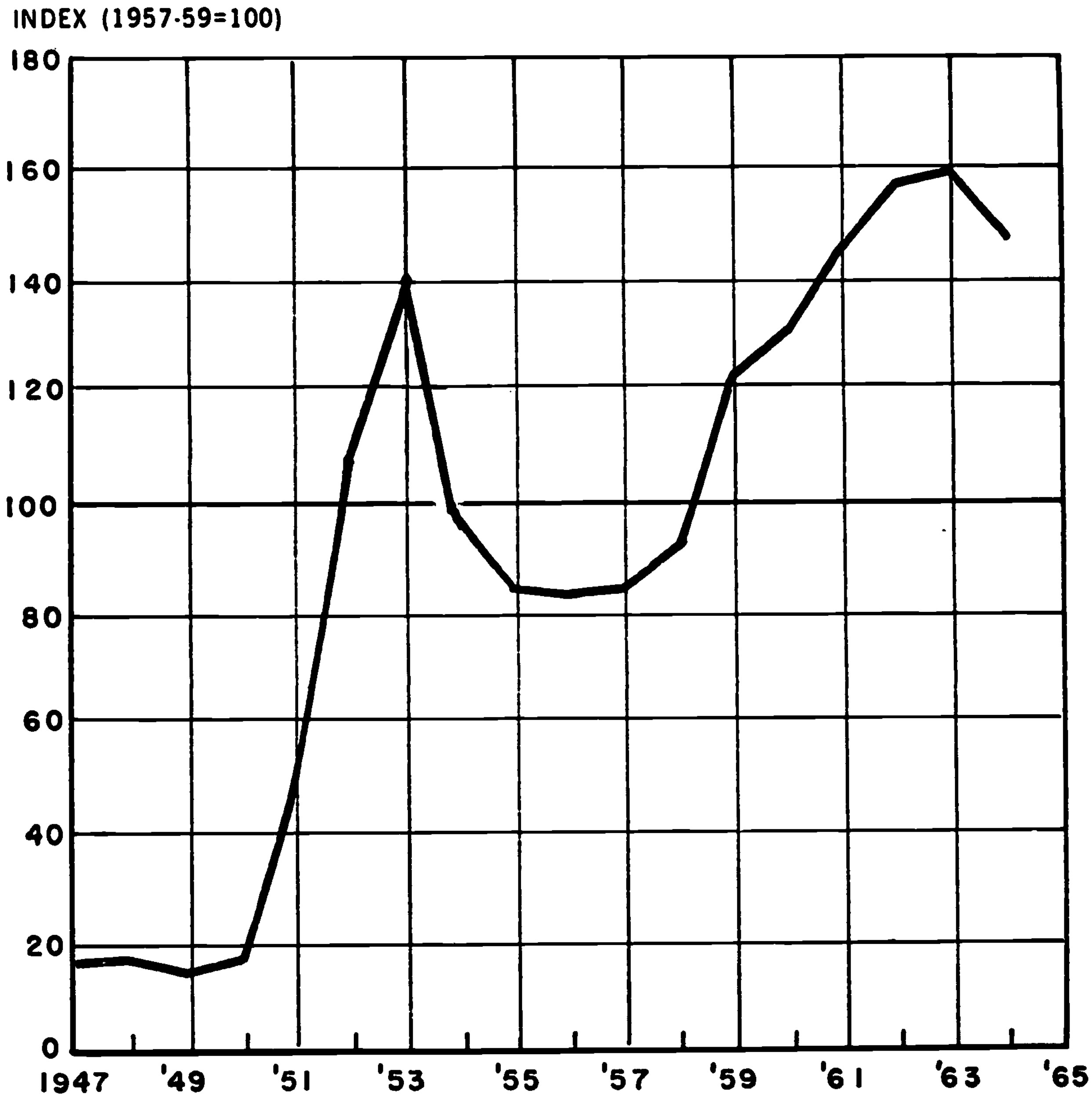
Technological developments in the ordnance industry group will continue to increase output per worker and affect the occupational composition of the industry.

A very important technological change affecting employment in ordnance establishments is the development of numerically controlled machine tools (N/C). Tape-controlled tools are particularly important in short production runs common in prototype development of missiles and spacecraft. A rapid rise in the number of N/C machines in use during the 1964–75 period could substantially limit employment opportunities in various machining occupations. For example, employment requirements for machine tool operators may be reduced somewhat by the widespread use of N/C machines. Requirements for highly skilled craftsmen, such as toolmakers and setup men, also would be reduced since fewer jigs, fixtures, and machine setups would be required. On the other hand, the use of numerically controlled machines would increase requirements somewhat for specially trained workers, particularly for jobs in computer operation and machine tool maintenance. It is possible that machining workers skilled in the operation of conventional machines could be trained to perform these jobs.

Automatic transfer equipment is another development that will continue to limit employment

EMPLOYMENT IN ORDNANCE AND ACCESSORIES, 1947-64

	Employment (in 000's)
1947	27
1948	28
1949	26
1950	30
1951	77
1952	179
1953	234
1954	163
1955	141
1956	139
1957	140
1958	158
1959	204
1960	220
1961	244
1962	264
1963	266
1964	247



Source: Bureau of Labor Statistics

growth in ordnance. Such equipment has been used increasingly to link machining operations, primarily in the manufacture of small arms. The employment impact of such equipment will fall heaviest on machine operators.

New job skills will be needed by metalworkers to form the metals that are required in missiles and space vehicles. New processing techniques now under development or in limited use include new high energy metal forming methods, brazing with new compounds; new adhesive bonding methods; welding and cutting with electronic beams; and nonmechanical metal removal methods, such as chemical milling and electrochemical machining.

Computer applications in this industry, which now range from accounting and production control to scientific and engineering computations, are expected to have both employment reducing and employment generating effects. Laborsavings will occur chiefly in routine clerical work, such as billing, posting, filing, and maintaining records, and in some office machine operations, such as tabulating and bookkeeping. Computers will also tend to reduce employment in certain types of quality control and warehousing jobs as a result of improved production standards and tighter inventory control. Requirements for lower and middle management employees also may be reduced because of the centralization and coordination of managerial functions. Computers, however, may extend man's capabilities and produce conditions favorable to employment growth, especially of scientists, engineers and technicians. A notable example of computer generated employment in this industry is in the research, design, and testing of missiles, space vehicles, and their components. Present successes with computers in ordnance research and development indicate that even more extensive use will be made of computers in the future to aid in the development of new products and processes.

Food and Kindred Products (SIC 20)

Summary

Employment requirements in the food and kindred products major industry group are expected to decline slightly between 1964 and 1975. Technological change is expected to be a significant factor in increasing output per worker through the mid-1970's.

Employment Trends

1947–64. Employment in the food and kindred products major industry group declined from about 1.8 million in 1947 to about 1.75 million in 1964, but the industry remained the largest employer in the manufacturing division. During this period, the proportion of production workers in food manufacturing dropped from nearly 78 percent to about 66 percent.

The food and kindred products major industry group includes all establishments processing foods and beverages for human and animal consumption. Five industry groups accounted for nearly four-fifths of total employment in 1964: meat products (18 percent); bakery products (17 percent); dairy products (17 percent); canned and preserved foods, except meats (15 percent); and beverages (12 percent). Employment in these five industry groups totaled nearly 1.4 million. The remaining workers were employed in four industry groups—grain mill products (7 percent); confectionery products (4 percent); sugar (2 percent); and miscellaneous food preparations (8 percent).

Employment trends have differed somewhat among the individual industry groups. For example, in meat products establishments—the largest food industry group—employment rose from about 275,000 in 1947 to about 338,000 in 1956, an increase of about 23 percent, then declined to approximately 314,000 in 1964. Employment in the bakery industry group, about 281,000 in 1947, increased to 304,000 in 1956, before declining to 290,000 in 1964. In the dairy products industry group, employment dropped from about 319,000 in 1958[9] to approximately 290,000 in 1964. On the other hand, employment in the sugar industry group was approximately the same in 1964 as in 1947.

1964–75. Employment requirements in food and kindred products establishments are expected to decline to about 1⅔ millions, or about 5 percent, by 1975, despite a rising demand for food, especially highly processed food that needs less preparation in the home, by a growing population with higher incomes.

Employment trends for the individual industry groups are expected to vary somewhat because of differences in levels of demand and the impact of technological developments. For example, worker requirements in the meat products industry group are expected to decline slightly, although production is expected to increase significantly. In contrast, moderate employment gains are expected in the canned and preserved food industry group.

[9] BLS employment (payroll) data for the dairy products industry group are not available for the years prior to 1958.

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Many establishments within this industry group are highly mechanized but others are smaller and may not become highly mechanized for some time. Growing consumer demand for geriatric, dietetic, and other specialty foods should contribute to a rise in employment requirements in this industry group.

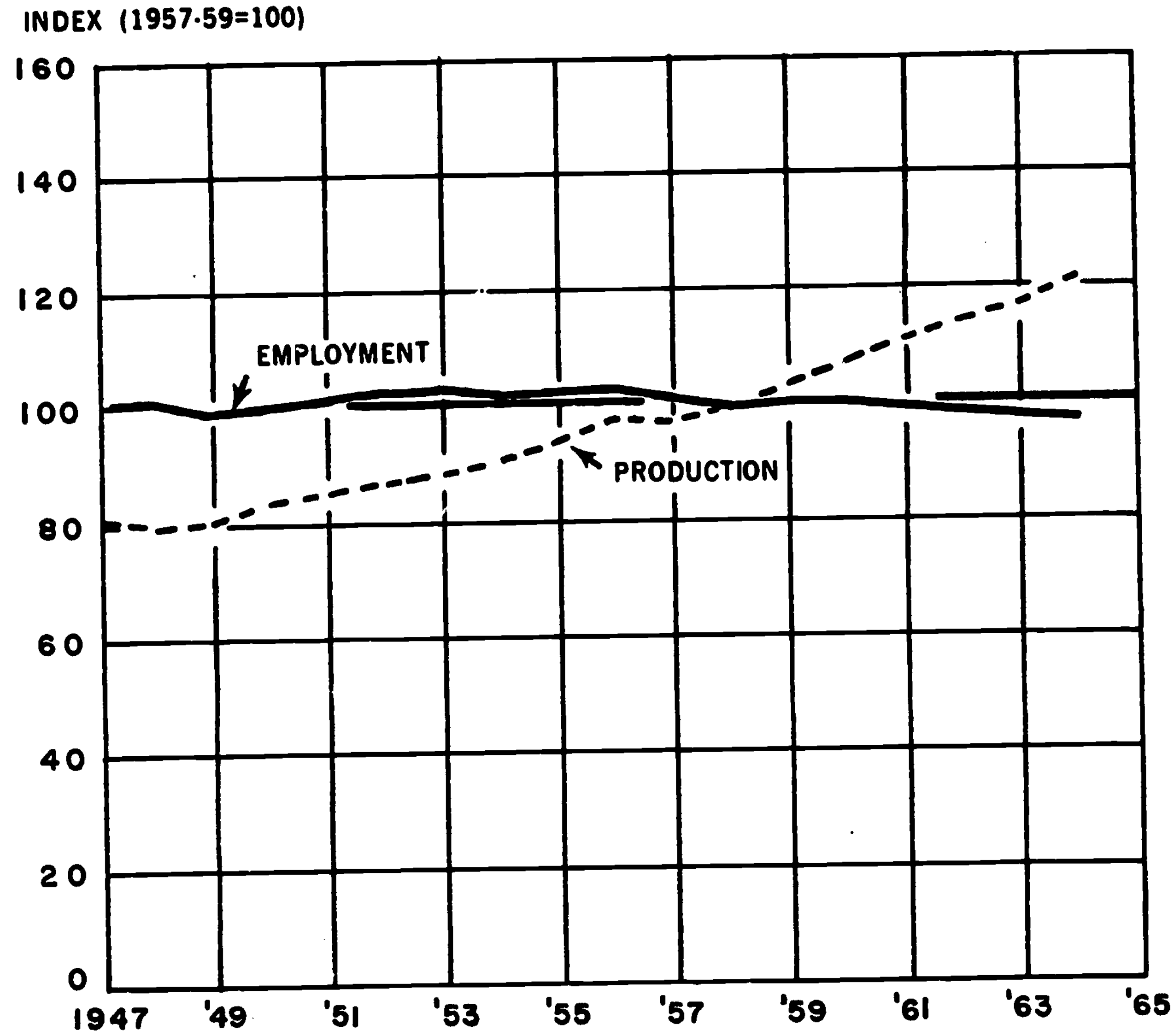
Effects of Technological Developments on Future Employment

During the next decade, technological innovations are expected to reduce unit labor requirements in virtually all types of food processing establishments. Among the technological innovations that should increase output per worker are the more widespread use of improved conveyor and transfer systems to handle food in process; computers and environmental sensors to control preparation of food; and automatic equipment to grade, weigh, and package a greater variety of foods. In addition, the greater use of improved materials handling systems, more closely designed for the work situation, could reduce the number of warehouse and shipping platform workers required. The application of electronic data processing, particularly for accounting and for information storage and retrieval in larger establishments, could limit employment opportunities for management, sales, and especially, clerical workers. Improved communications to further coordinate and integrate activities among the various functional areas of an establishment and between geographically scattered divisions of an organization could also limit employment opportunity. The economies of scale made possible by improvements in equipment and methods (such as freezing processes in the baking industry) may be expected to continue the trend to larger, but fewer, food processing establishments in many food industries.

Specific examples of recent technological innovations that will continue to increase output per

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN FOOD AND KINDRED PRODUCTS, 1947-64

	Employment (in 000's)
1947	1,799
1948	1,801
1949	1,778
1950	1,790
1951	1,823
1952	1,828
1953	1,839
1954	1,818
1955	1,825
1956	1,842
1957	1,805
1958	1,773
1959	1,790
1960	1,790
1961	1,775
1962	1,762
1963	1,752
1964	1,746



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

employee in the food industry include the following: (1) In meatpacking, the growing use of automatic bacon slicers, sausage stuffers, and frankfurter machines has reduced requirements for workers, particularly women, engaged in processing these products. A new "on-the-rail" dressing technique and a fast cure system for pork products have reduced labor requirements in these processes. Increasing use is being made of electric stunners and saws, compressed air knives, and mechanical hide strippers in cattle slaughtering, and of special machines to clean and dress poultry; (2) in the processing of dairy products, more widespread use of instantaneous pasteurization methods, and seamless, continuous piping systems (which can be cleaned in-place), should continue to increase output per worker; (3) in flour milling, increased reliance on laboratory analysis and monitoring instrumentation to check ingredients before and during processing should reduce the need for millers.

The adverse effects on employment in the food products industry groups will probably weigh most heavily on operatives and laborers such as food graders, washers, and inspectors; food processing machine operators; warehouse and shipping workers; and routine clerical employees. Technological changes also will adversely affect employment requirements for skilled workers such as bakers and brewers. These adverse effects, however, will be offset to a small degree by the need for instrument repairmen and other mechanics to maintain and repair equipment of growing complexity.

The future employment impact of some new food processing techniques such as the freeze-dry process, very low-temperature freezing, and food preservation through atomic radiation is difficult to assess at present. The widespread use of these techniques could make available a greater variety of foods during all seasons of the year, but their employment generating effects would be negligible if these foods merely served as substitutes for others and the new techniques were integrated into existing automatic food processing systems.

Tobacco Manufactures (SIC 21)

Summary

Employment requirements in the tobacco manufactures major industry group are expected to continue to decline slightly between 1964 and 1975. Technological change is expected to be a major factor in the employment decline in this major industry group through the mid-1970's.

Employment Trends

1947–64. Employment requirements in tobacco manufacturing, the smallest of all manufacturing major industry groups, declined from 118,000 to about 89,000 between 1947 and 1964, a decline of 25 percent. During the same period, the production of all tobacco products, including cigarettes, cigars, smoking and chewing tobacco, and snuff, increased about 48 percent.

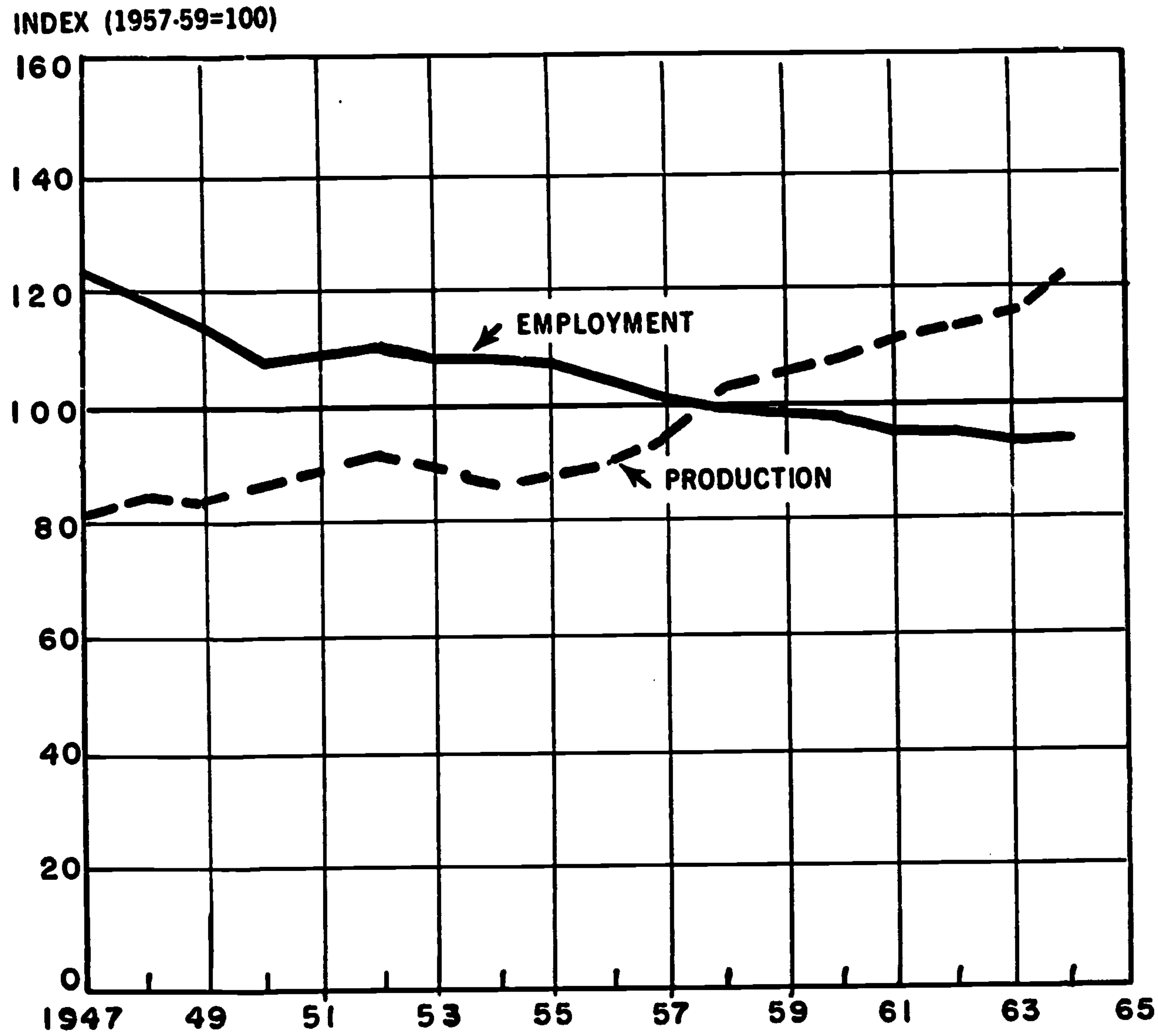
About 70 percent of the total employment in tobacco manufacturing in 1964 was concentrated in two industries—cigarettes, with more than 40 percent, and cigars, with almost 30 percent. The remaining workers were employed in establishments producing smoking and chewing tobacco and snuff and in tobacco stemming and redrying establishments.

Between 1947 and 1964, the trends in employment in the cigarette and cigar industries differed widely, reflecting differences in product demand and the rates of introduction of laborsaving technology. Employment increased rapidly (about 27 percent) in establishments producing cigarettes, as increased demand for the industry's products created a need for additional workers. In 1963, per capita consumption of cigarettes by persons 15 years of age or over reached a record high of 200 packs. Employment in cigar manufacturing establishments declined nearly 50 percent between 1947 and 1964, as the increasing use of mechanized laborsaving equipment significantly increased output per worker.

1964–75. Manpower requirements in tobacco manufacturing are expected to decline by about 10 percent between 1964 and 1975, to 80,000. Production of tobacco products is expected to be stimulated by rising consumption of tobacco products resulting mainly from population growth. However, it should be noted that the controversy over smoking and health, particularly cigarette smoking, continues to create uncertainty about the market for tobacco products. Information programs and restrictive legislation intended to discourage cigarette smoking may tend to increase the consumption of cigars and pipe tobacco. Also, both cigar and cigarette manufacturers are expected to expand their product lines in an effort to gain increased consumer acceptance. Nevertheless, laborsaving technological developments in this already highly mechanized industry group are expected to more than offset increases in the production of tobacco products.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN TOBACCO MANUFACTURES, 1947-64

Employment (in 000's)	
1947	118
1948	114
1949	109
1950	103
1951	104
1952	106
1953	104
1954	103
1955	103
1956	100
1957	97
1958	95
1959	95
1960	94
1961	91
1962	91
1963	89
1964	89



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

Effects of Technological Developments on Future Employment

Laborsaving technological innovation in tobacco production is expected to have a significant effect on the number and characteristics of jobs within the industry through the mid-1970's. Technological laborsaving developments will be particularly significant in the cigar industry. The expanding use of processed tobacco, composed of natural leaf materials that are finely ground and reconstituted into a continuous uniform sheet, will make possible substantial savings in material and labor in the manufacture of cigars. It is used widely as a binder and to a limited, though increasing extent, as a wrapper in place of natural leaf. The increasing use of sheet tobacco in automatic cigar making machines is expected to reduce requirements for machine operators.

In addition to attachments for applying processed wrapper and binder, other accessory equipment is increasing efficiency in cigar manufacturing. For example, a cigar accumulator that automatically collects finished cigars makes possible increased machine speeds by eliminating manual collection by the wrapper layer operator. This is a particularly significant advance for those production lines where natural leaf wrappers will continue to be used. Another new device designed as an integral part of the making machine attaches mouthpieces to cigars with no reduction in the rate of output. The increasing mechanization of cigar manufacturing is raising the employment requirements for maintenance and repair workers, such as mechanics, responsible for keeping this complex equipment in good working order.

Further integration of cigar manufacturing processes also are expected. The connection of such equipment as wrapping and banding machines with cartoning machines reduces cigar handling and will adversely affect requirements for cigar packers. Full integration of processing equipment from making through wrapping, banding, and cartoning has been accomplished in some large plants.

Cigarette manufacturing, using highly mechanized equipment, is now a continuous process of wrapping, cutting, inspecting, and packaging. Modifications made in cigarette machines in the last decade have increased their operating speed substantially. A new type of cigarette making machine, recently introduced in the industry, makes possible further increases in production rates. Highly efficient equipment for attaching filter plugs to cigarettes has become an integral part of the making machine in recent years. In addition, some plants are joining making machines in pairs, permitting a reduction of one-half in the number of operators of these machines.

Increased emphasis on improved product quality and production efficiency is expected to result from the growing use of precision instruments to measure the performance of making machines. For example, an electronic device has been developed that can check the quality and weight standards of 2,000 cigarettes in less than 2 minutes compared with 3 to 4 hours required for hand inspection. Another device monitors the operation of filter plug making machines and controls the diameter of the plugs as they are produced. Such developments are expected to reduce requirements for inspectors while boosting requirements for maintenance and repair workers such as instrument repairmen.

Textile Mill Products (SIC 22)

Summary

Employment requirements in the textile mill products major industry group are not expected to change very much between 1964 and 1975, despite an anticipated substantial increase in the output of textiles. Technological change is expected to continue to be a significant factor in increasing output per employee.

Employment Trends

1947–64. Employment in textile mills dropped from about 1.3 million in 1947 to 891,000 in 1964, despite a 45-percent increase in production.

In 1964, one-half of the total employment in this major industry group was divided almost equally between the two largest industry groups—cotton broad woven fabrics and knitting. Three other industry groups—yarn and thread; silk and synthetic broad woven fabrics; and finishing textiles, except wool and knit—accounted for 30 percent of all workers. The remaining four industry groups—weaving and finishing broad woolens, floor covering, narrow fabrics and smallwares, and miscellaneous textile goods combined—employed about one-fifth of the workers.

Between 1958 and 1964,[10] employment rose in five textile mill products industry groups, but employment declines in four other groups more than offset these gains. The differences in employment trends among the industry groups reflected mainly the differences in the levels of product demand and in the application of laborsaving technological innovations. For example, the rapidly growing demand for synthetic fabrics caused employment in establishments producing synthetic broad-woven fabrics to rise about 14 percent, despite the introduction of new, more efficient machines and methods to treat manmade fibers. On the other hand, the relatively slight change in the production of wool fabrics in combination with increasing output per worker (resulting from the growing use of improved looms and other laborsaving innovations) caused employment in wool weaving and finishing establishments to decline by about 22 percent.

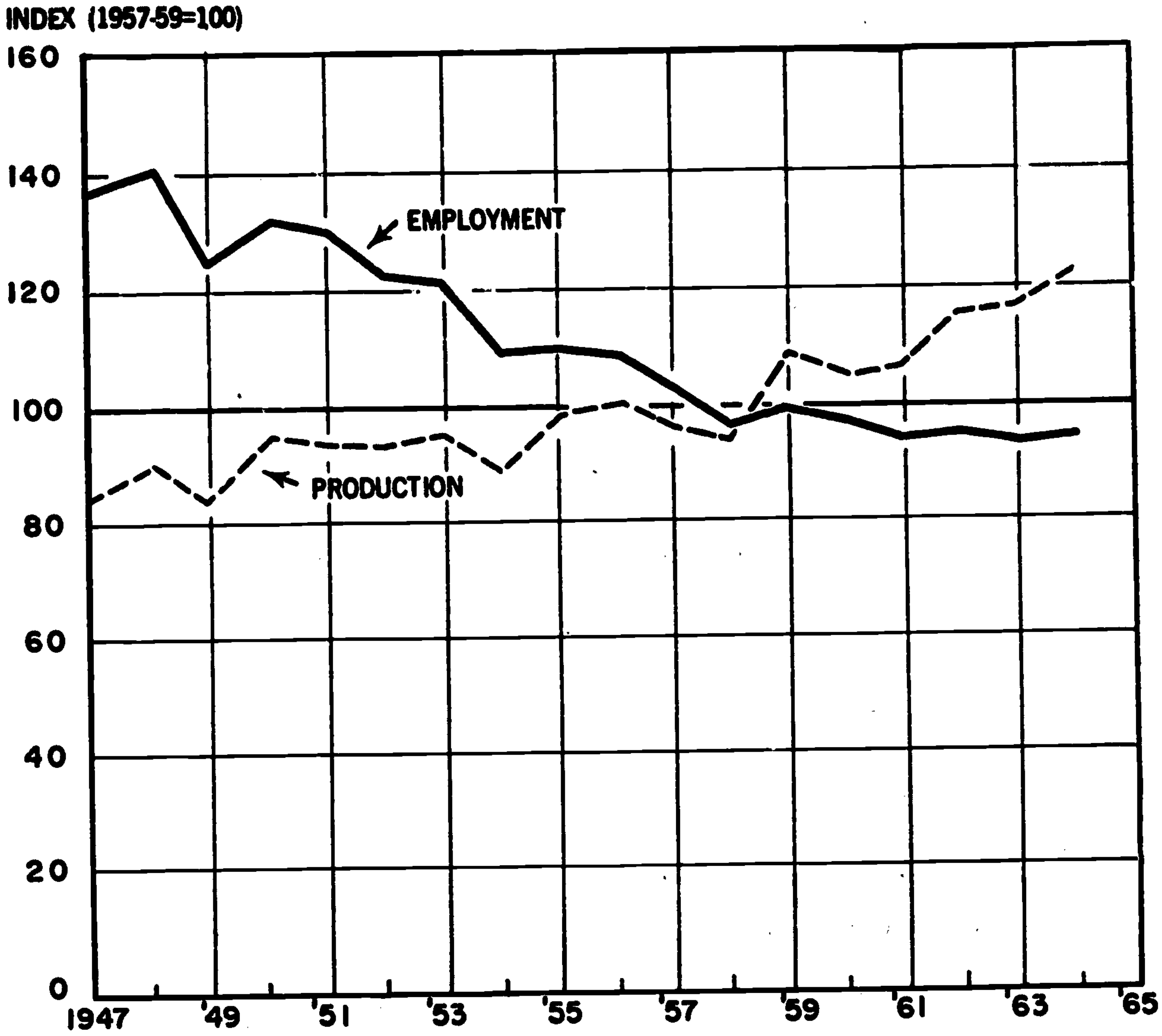
1964–75. Employment requirements in the textile mills are expected to be about 880,000 in 1975, not much different than in 1964, assuming no significant change in the importance of imports and exports. Production is expected to increase during this period, stimulated by factors such as increasing population (especially teenagers and young adults who are major consumers of clothing) and rising family formations and personal disposable income (which should stimulate demand for such products as carpets and drapes as well as clothing). In addition, expenditures for research and development in the fields of synthetic fibers and natural fibers and fabrics are expected to increase. Such activities can be expected to result in new fabrics and synthetic fibers that open new markets for textile mill products.

Although the textile industry will continue to be one of the major industrial employers in the Nation, employment requirements are not expected to keep pace with output. Labor requirements

[10] BLS employment (payroll) data prior to 1958 are available only for three industry groups—knitting; yarn and thread; and finishing textiles, except wool and knit.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN TEXTILE MILL PRODUCTS, 1947-64

Employment (in 000's)	
1947	1,299
1948	1,332
1949	1,187
1950	1,256
1951	1,238
1952	1,163
1953	1,155
1954	1,042
1955	1,050
1956	1,032
1957	981
1958	919
1959	946
1960	924
1961	893
1962	902
1963	885
1964	891



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

are anticipated to increase in some industry groups (including knitting, yarn and thread, floor covering, and synthetic broadwovern fabrics), but these gains will be more than offset by declining requirements in others. Throughout all textile mill products industry groups, the growing application of laborsaving technological innovations is expected to increase output per worker.

Effects of Technological Developments on Future Employment

Output per textile mill worker is expected to increase in the decade ahead because of the increasing use of laborsaving technological innovations, including faster, higher capacity machines; improved methods of material handling; and increasing application of continuous manufacturing techniques.

Faster machine speeds are expected to reduce unit labor requirements for operatives such as card tenders, comber enders, drawers, roving hands, spinners, and weavers. For example, new carding and drawing machines operate at more than three times the speed they did 10 years ago; spindle speeds were 10,000 r.p.m. in 1950, are now 13,500 r.p.m., and as much as 20,000 r.p.m. are possible; winding speeds are at least double that of 10–15 years ago; and loom speeds have increased substantially. Probably more importantly, the use of improved yarns results in fewer loom stops and allows operators to watch more looms with less effort. The greater use of new and improved conveyor systems for the transfer of textile materials during manufacture is expected to reduce the need for laborers, such as truckers and warehousemen. Electronic monitoring systems are expected to be used increasingly, reducing labor requirements for quality control. Requirements for unskilled workers, such as cleaners and oilers, will be reduced by the increasing utilization of automatic cleaning devices and automatic lubrication systems for spinning, twisting, weaving, and other types of textile machinery. Progress is also anticipated in developing automatic manufacturing techniques. A number of new spinning and weaving plants now being constructed will use the latest techniques in automated systems and specialized equipment to improve the flow of production and eliminate many operations performed by spinners, weavers, and other operatives. Under development is a completely automatic dyeing process that may need manual attention only in emergency situations. Better layouts of machines and plants will also increase manufacturing efficiency. In addition, synthetic fibers, which require fewer mill operations than natural fibers, are anticipated to account for a growing proportion of textile mill output.

Although changing technology is expected to reduce employment requirements in some textile mill occupations, it will increase employment in others. For example, requirements for engineers, technicians, machine maintenance men, and repairmen are expected to increase because of the growing complexity and number of instruments and machines in use—including devices that photoelectrically detect defects in yarn; automatic tying devices that repair breaks in yarns; time and temperature devices that control dyeing machines; automatic machines that duplicate previously run styles, colors, and finishes without test runs or variations; and electronic data processing applied in such functions as market analysis, production scheduling, and inventory control.

Apparel and Related Products (SIC 23)

Summary

Employment in the apparel and related products major industry group is expected to increase moderately through the mid-1970's, somewhat faster than during 1947–64. Technological change is expected to have a relatively modest impact on employment requirements in this labor intensive industry.

Employment Trends

1947–64. Employment in the apparel and related products major industry group increased by 148,000 during the post-World War II period, a gain of 13 percent. The increase in employment was primarily a result of the rising demand for apparel brought about by increases in population and personal disposable income, although employment did not grow as rapidly as the production of apparel. During the post-World War II period, the production of apparel increased by about 80 percent. The disparity between employment and production trends can be attributed primarily to (1) the growing popularity of casual wear, which requires less labor to produce than formal wear; (2) the emergence of large, highly efficient firms; and (3) innovations in production equipment and materials handling systems.

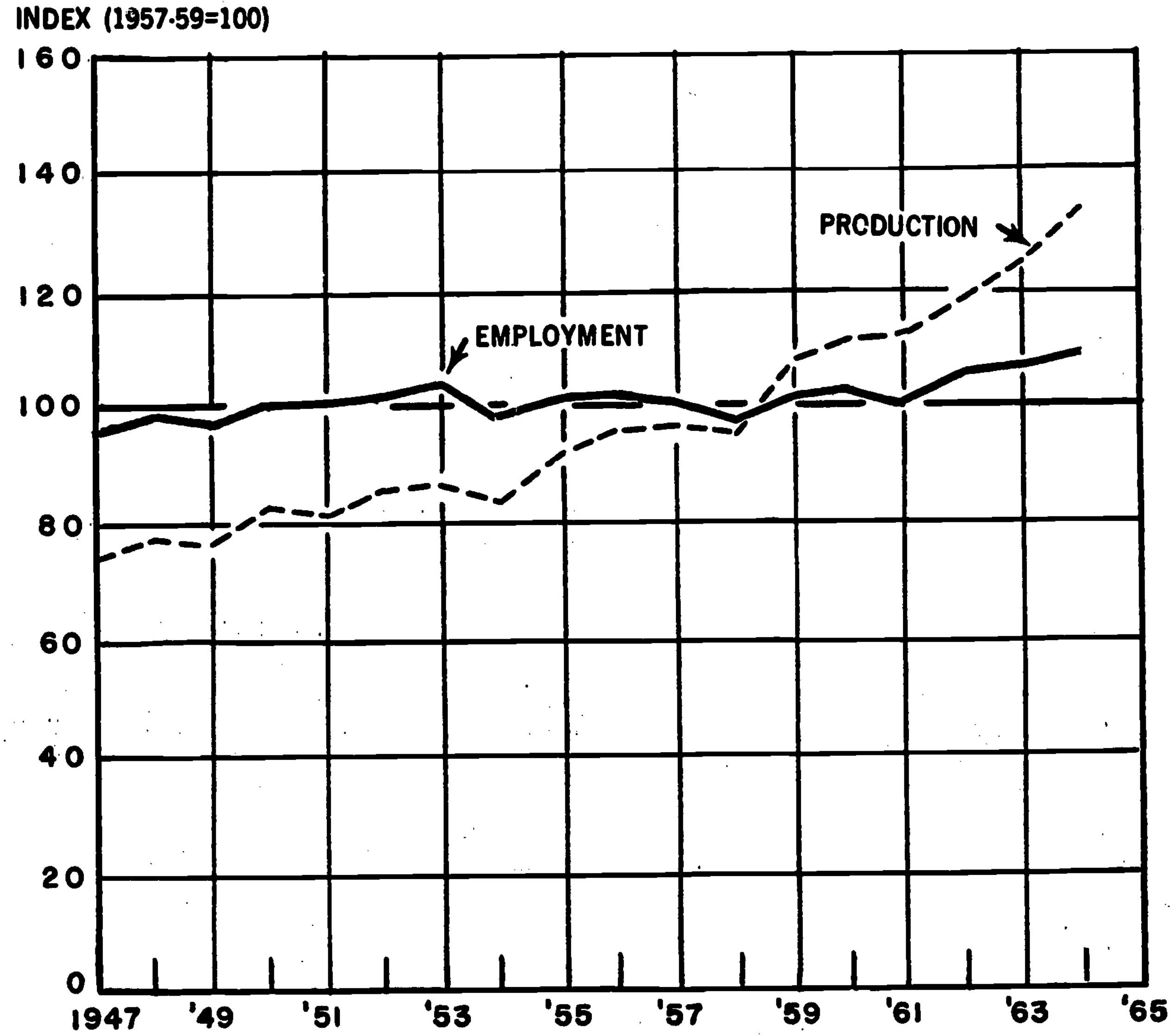
More than a third of the 1.3 million apparel workers employed in 1964 made clothing for men and boys, about 30 percent made women's outerwear, and about 12 percent worked in establishments producing fabricated textile products. The remaining workers were employed in establishments making women's and children's undergarments; hats, caps, and millinery; girls' and children's outerwear; and fur goods and miscellaneous apparel.

Employment trends between 1947 and 1964 varied considerably among the various apparel manufacturing industries reflecting factors such as the increasing demand for casual wear and changes in the age composition of the population. Employment increased most rapidly (47 percent) in the industry group producing girls' and children's outerwear. In contrast, employment in the industry producing women's, misses', and juniors' outerwear increased about one-fifth (20.2 percent). The difference between these two trends was largely a result of a rise in the proportion of children in the population. Even more striking is the difference between employment trends in the industry producing men's and boys' suits and coats, which decreased 23 percent, and the industry producing men's and boys' furnishings, which increased 24 percent. Production in the latter industry was stimulated significantly by the growing preference for casual wear. Conversely, production increases in the men's and boys' suits and coats industry were limited by the declining popularity of more formal wear.

1964–75. Manpower requirements in the apparel and related products industry are expected to increase moderately in the years ahead, assuming no significant change in the importance of imports and exports. By 1975, employment in this industry may reach 1.5 million, about 17 percent higher than the 1.3 million workers employed in 1964. The annual rate of employment growth during the next decade (1.4 percent) implied by the projections is slightly higher than the annual rate between 1954 and 1964 (1 percent).

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN APPAREL AND RELATED PRODUCTS, 1947-64

Employment (in 000's)	
1947	1,154
1948	1,190
1949	1,173
1950	1,202
1951	1,207
1952	1,216
1953	1,248
1954	1,184
1955	1,219
1956	1,223
1957	1,210
1958	1,172
1959	1,226
1960	1,233
1961	1,215
1962	1,264
1963	1,283
1964	1,302



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

Employment expansion in this industry is predicated on a rapidly increasing demand for apparel from a growing, more affluent, and younger population. The anticipated growth in population and personal disposable income should contribute substantially to a growing demand for apparel, and fabricated textile products for the home. Of particular importance to apparel production and sales, however, is the anticipated increase in the proportion of the population 14 to 34 years of age—generally, the largest consumers of apparel. Those in this age group, who at present represent about 41 percent of the population, are expected to comprise about 46 percent of the population in 1975.

Effects of Technological Developments on Future Employment

Technological developments in the apparel and related products industry during the next decade are expected to have relatively limited impact on employment requirements and output per worker should not increase much faster than in the post-World War period. Although mechanization of many of the production operations in this industry is technically feasible, the nature of the industry's products and market limits the application of mechanization. For example, changing and varied consumer preferences dictate a variety of clothing styles for each season of the year and frequent styling changes. Therefore, manufacturing operations have to be flexible. Generally, mechanized equipment has lacked flexibility. Morever, although there is a trend toward larger size apparel firms, most firms in the industry are small and lack the capital to invest in expensive equipment. Nevertheless, because of the expected increase in the size of apparel firms and rising research and development expenditures to improve apparel production operations, a gradual increase in the use of mechanized equipment and other laborsaving devices is anticipated in this industry. Most new highly mechanical equipment will be used in the sewing, cutting, and pressing operations of large plants.

Increasing mechanization of sewing room operations is anticipated in plants that produce a large volume of items not subject to frequent styling changes, such as shirts, undergarments, and work clothing. For example, a leading manufacturer of shirts recently purchased a machine that performs many stitching operations, including setting up each section of material for sewing, guiding the material through the sewing process, cutting thread at the completion of the servicing operation, and stacking sewed shirt panels. Another new machine available to the industry assembles shirt cuffs. This machine automatically selects cuff components, matches, stitches, presses, buttonholes, attaches buttons, and performs many other operations without manual assistance. The widespread use of machines similar to these would limit somewhat the employment growth of sewing machine operators.

Technological developments in the cutting and pressing rooms may affect employment requirements for manual operators, such as markers, cutters, pressers, and graders. For example, the growing application of new photographic methods for predetermining the marking of material before cutting may reduce the need for markers. The more widespread use of automatic die-cutting machines for batch cutting of components for standardized items such as shirts and work clothing is expected to limit the employment growth of cutters. A recent development is the use of computers for calculating data on pattern variations needed for size differences. If this development gains wide acceptance in the industry, it may limit the employment growth of pattern graders. The increased use of improved pressing techniques, such as the application of steam jets through mannequins or forms, may limit the employment growth of pressers.

Lumber and Wood Products, Except Furniture (SIC 24)

Summary

Employment requirements in the lumber and wood products major industry group (lumber industry) are expected to continue to decline through the mid-1970's, but at a slower rate than between 1947 and 1964. Increasing output per worker will continue to more than offset increases in output.

Employment Trends

1947–64. Employment in the lumber industry fell from 845,000 to about 603,000 between 1947 and 1964—a decline of about 29 percent. This occurred primarily as a result of increased mechanization, which increased output per worker more than enough to offset gains in production. Lumber output increased more slowly than it might have because of the growing use of other materials in construction, packaging, and manufacturing.

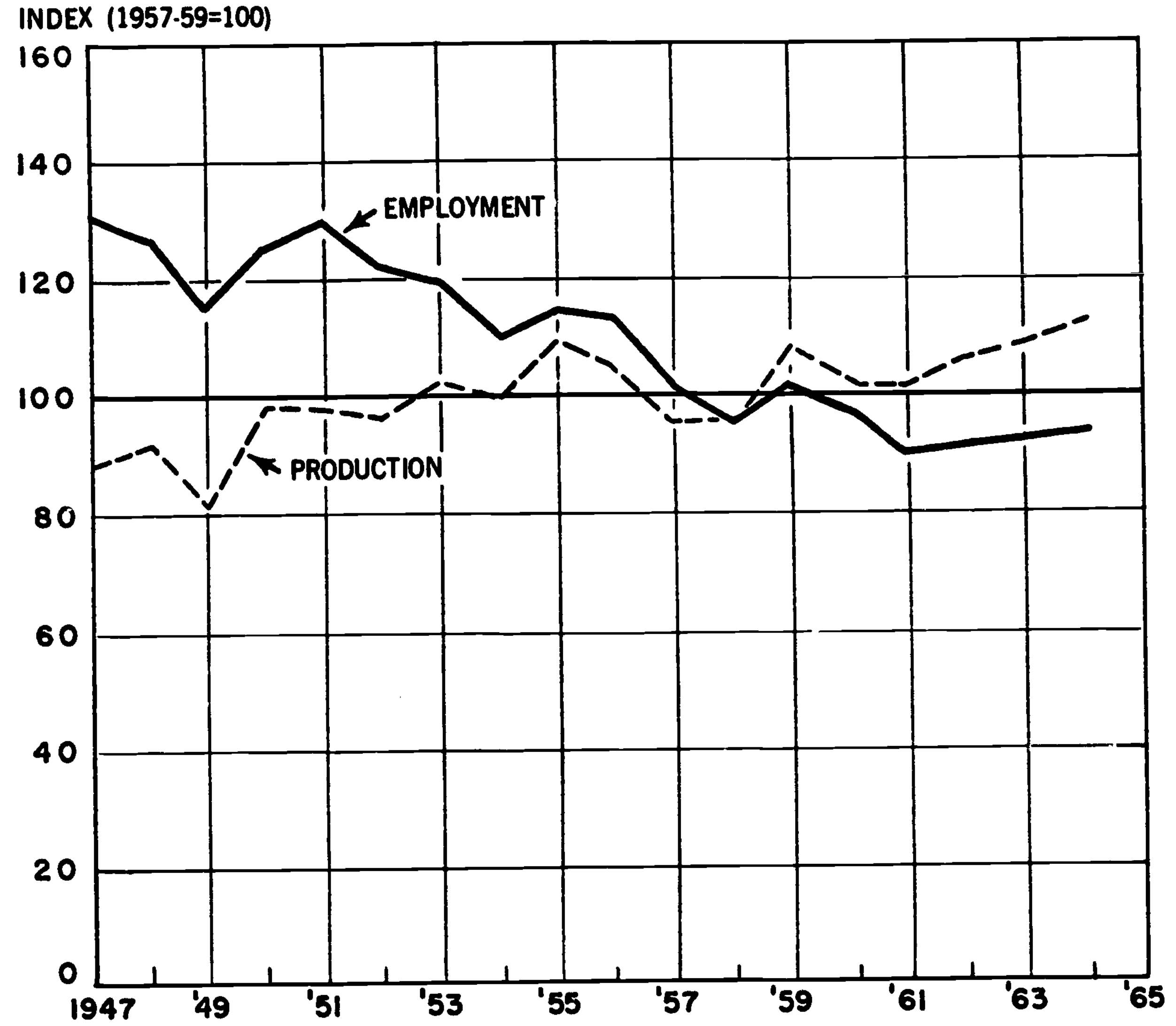
In 1964, 42 percent of the lumber workers were employed in establishments engaged primarily in sawing and planing lumber and 26 percent were employed in establishments producing millwork, plywood, and prefabricated structural wood products. Smaller numbers of workers were employed in logging camps and by logging contractors (14 percent) and by miscellaneous wood products establishments (12 percent). The remaining workers (6 percent) were employed in establishments producing wooden containers.

During the 1947–64 period, employment changes varied widely among the industry groups, reflecting different rates of change in production trends and in the impact of laborsaving technological innovations. For example, employment declined by about one-half in sawing and planing establishments, and in establishments producing wooden containers. In contrast, employment increased by slightly more than one-fourth in establishments producing millwork, plywood, and related products. Logging camp and logging contractor employment and miscellaneous wood products employment remained relatively stable.

Employment in sawmills and planing mills decreased primarily as a result of increasing mechanization, improved plant layout, and a reduction in the number of establishments. These developments were more than sufficient to offset the increase in the production of lumber. On the other hand, employment declined in establishments producing wooden containers, primarily as a result of a decline in the demand for these products. In only one industry group—millwork, plywood, and related products—was there a substantial increase in employment, stimulated by a substantial increase in output. This increased output resulted from the growing demand for products produced in these establishments for use in construction and manufacturing. However, much of this increase in usage was at the expense of products produced by sawing and planing mills. Employment in establishments producing miscellaneous wood products also increased, again reflecting the

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN LUMBER AND WOOD PRODUCTS, 1947-64

	Employment (in 000's)
1947	845
1948	818
1949	741
1950	808
1951	840
1952	790
1953	771
1954	708
1955	740
1956	731
1957	655
1958	615
1959	659
1960	627
1961	583
1962	589
1963	593
1964	603



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

strong demand from the construction industry for wood products, especially particle board.

1964–75. Manpower requirements in this major industry group are expected to decline to about 550,000 by 1975, an annual rate of decrease of .8 percent compared with 1.5 percent between 1947 and 1964. Employment is expected to decline despite anticipated increases in demand for lumber and wood products resulting from rising levels of construction and manufacturing activity. In addition, the lumber industry's continuing emphasis on research and development programs is expected to increase the markets for many wood products.

Employment trends among the individual industries are expected to continue to differ. The increasing demand for millwork, plywood, and related products and miscellaneous wood products is expected to cause employment in establishments manufacturing these products to increase slightly. Items such as wooden panels, plywood, millwork, and particle board are expected to be in much greater demand in the future, reflecting increased use by construction and manufacturing industries. However, manpower requirements will not increase as fast as output because of increasing mechanization.

Manpower requirements in sawing and planing mills will continue to decline as the impact of laborsaving innovations more than offsets increased output. In addition, plywood and veneer products are expected to continue capturing markets now held by lumber, thus limiting growth in the demand for lumber.

A decline in logging camp and logging contractor employment also is expected. Although demand is expected to accelerate for many types of forest products, continued improvements in the harvesting and transporting of logs will tend to limit manpower needs.

Employment in establishments producing wooden containers is expected to continue to decline through the mid-1970's. Containers made o metal, plastic, and paperboard will continue to offer strong competition to wooden containers in the years ahead, especially since these substitute containers are generally lighter and more durable. Manpower needs in these establishments also will tend to be limited by increasing mechanization.

Effects of Technological Developments on Future Employment

Technological developments will continue to have a substantial impact upon the number and characteristics of jobs in the lumber industry through the mid-1970's. Although this major industry group is already highly mechanized, continued modernization of facilities is expected during the coming decade. Increasing mechanization and greater utilization of laborsaving machines is expected. Greater mechanization in the lumber industry should stimulate requirements for repairmen and other skilled workers and reduce requirements for unskilled workers. As the lumber industry does more research and quality control of wood products, the need for technicians and research people should increase.

Changes in logging operations in the 1964-75 period may have a significant effect on employment in logging camps. More truck and tractor drivers will be needed, but the size of the cutting crew may be reduced as the equipment becomes more powerful and mobile. The use of balloons and helicopters in the transporting of logs could permit logging in woodlands having terrain that cannot be traversed economically by conventional equipment. Use of such equipment would increase requirements for pilots and balloon riggers and operators, while limiting the need for operators of conventional equipment.

In sawing and planing operations, the increased use of conveyor belts, electronic sorting devices, and higher speed equipment should increase operating efficiency, at the same time limiting the need for manual handling of material by unskilled laborers.

In the next 10 years, many new plywood and veneer manufacturing plants are expected to be built. These new plants will be highly mechanized, and require relatively few employees. The coming decade should see additional closing of marginal plants and companies in the lumber industry. These mills and companies will be forced to close or merge because of intensive competition and increased productivity in the more modern mills.

Furniture and Fixtures (SIC 25)

Summary

Employment requirements in the furniture and fixtures major industry group are expected to increase by more than one-fourth in the 1964-75 period, despite significant increases in output per worker.

Employment Trends

1947-64. Employment in this major industry group increased from 336,000 to 406,000 between 1947 and 1964, an annual rate of about 1 percent.

In 1964, nearly three-fourths of the workers in this major industry group worked in establishments producing household furniture, such as sofa beds, studio couches, and mattresses and bedsprings. Slightly less than one-tenth of the workers were employed in establishments engaged in manufacturing partitions, shelving, lockers, and office and store fixtures. More than one-tenth of the workers were employed in establishments producing public building and related furniture, and miscellaneous furniture and fixtures. The remaining workers were employed in establishments making office furniture.

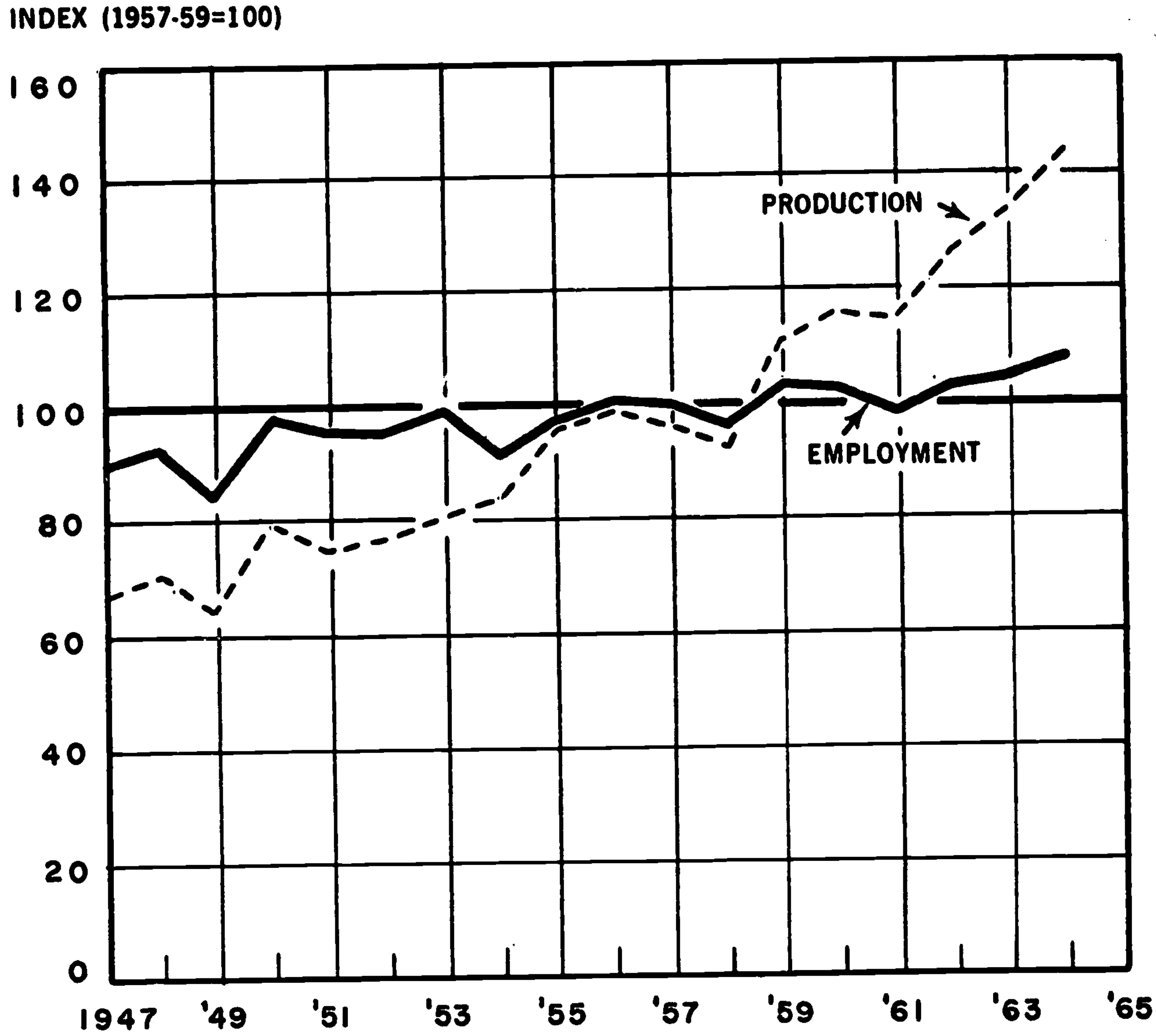
The employment growth rates were similar among the industries of this major group between 1958-64.[11] The greatest increase in employment occurred in establishments producing household furniture, almost 13 percent. Employment increased by more than 10 percent in establishments engaged in manufacturing office furniture; by about 13 percent in both the partitions, shelving, lockers, and store fixtures industry group, and in establishments producing other furniture and fixtures.

1964-75. Manpower requirements in this major industry group are expected to rise by about one-fourth between 1964 and 1975 to about 510,000. Demand for this major industry group's products is expected to increase rapidly during the next decade. However, increasing mechanization and larger factory units will tend to increase the efficiency of production and limit employment growth. Demand for household furniture will be stimulated by, among other things, continued increases in population, new family formation, rising disposable personal income, and the number of families with two homes. The anticipated increase in construction of commercial, industrial, and public buildings will contribute to high levels of demand for furniture, fixtures, and partitions.

[11] BLS employment (payroll) data for all furniture industry segments are available only for the years since 1958. However, data for two segments are available for earlier periods—since 1947 for household furniture and since 1951 for the partitions, office and store fixtures segment.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN FURNITURE AND FIXTURES, 1947-64

Employment (in 000's)	
1947	336
1948	346
1949	317
1950	364
1951	357
1952	357
1953	370
1954	342
1955	364
1956	376
1957	374
1958	361
1959	385
1960	383
1961	368
1962	385
1963	390
1964	406



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

Effects of Technological Developments on Future Employment

Technological developments will have a significant impact upon the number and characteristics of jobs in furniture manufacturing despite the small-scale operations and the lack of product standardization that now characterize plants in this major industry group. Examples of new equipment that are expected to reduce requirements for semiskilled workers producing wood furniture is the introduction of new automatic profilers and routers. A recently developed automatic profiler is said to shape parts 2 to 5 times faster than older methods of marking, handsawing, and handshaping. The router, a machine producing cutouts in wood or decorative carving over flat and curved surfaces, can be programed for an automatic and continuous course. Relatively unskilled operators need only to place material for the process.

In some manufacturing plants, automatic stackers, conveyors, and hoppers are replacing unskilled laborers employed to transfer materials between machines and processes. Recent innovations include the linking of machines, which reduces requirements for machine operators. In addition, the greater use of pneumatic power changers and assembly machines should reduce requirements for production workers in the assembly of frames, case ends, drawers, and chairs. One type of assembly machine in use can take parts from a tenoner machine, feed metal parts from hoppers, insert these parts, drive in up to eight pins or nails and eject the finished products on conveyors. Labor requirements for finishing are also being reduced through the use of infrared electric drying ovens. In addition, a recently developed drying and finishing system reportedly eliminates all manual handling in the finishing process and, in one modern plant, has reduced total drying and finishing time by 50 percent.

Paper and Allied Products (SIC 26)

Summary

Employment requirements in the paper and allied products major industry group are expected to increase from 625,000 in 1964 to about 775,000 in 1975. Production will rise substantially, primarily because of rising population, increased business activity, and higher per capita consumption of paper products. However, employment is expected to grow slower than production, because technological changes are expected to increase output per worker, particularly in the pulp, paper, and paperboard mills.

Employment Trends

1947–64. Employment in the paper and allied products major industry group increased from 465,000 to 625,000 between 1947 and 1964, or approximately 34 percent, as production more than doubled.

More than two-fifths of the employees engaged in the manufacture of paper and allied products in 1964 were in establishments manufacturing pulp, paper, paperboard, and building paper and board. Nearly one-third were in establishments making paperboard containers and boxes, including folding and setup paperboard boxes; corrugated and solid fiber boxes; sanitary food containers; and fiber cans, tubes, and drums. The remaining workers were in establishments producing converted paper products, such as coated and glazed papers, envelopes, and sanitary paper products.

Between 1958 and 1964,[12] employment growth among the three broad segments of this major industry differed widely, reflecting in part differences in the increase in product demand and in the rates of introduction of laborsaving technology. Employment increased rapidly in establishments producing converted paper and paperboard products, except containers and boxes. Additional workers were needed during this period to meet the increasing demand for the industry's products, particularly for coated and processed papers, sanitary tissue health products, and grocers' and multiwall bags. Multiwall bags have largely replaced textile bags as containers for such products as flour, sugar, and animal feeds, and are also used in packaging cement, certain chemicals, and fertilizers.

Employment in establishments making paperboard containers and boxes increased moderately between 1958 and 1964, reflecting the rapidly growing demand by industrial users for such products as corrugated boxes, pads, and partitions, folding paperboard boxes, and sanitary food containers.

Employment in establishments producing pulp, paper, paperboard, and building paper and board changed only slightly as the production increase between 1958 and 1964 was offset by increasing output per worker, resulting mainly from the growing application of technological innovations.

1964–75. Employment requirements in the major industry group are expected to rise by 24 percent between 1964 and 1975, to about 775,000. Production of paper and paper products is expected to rise rapidly through the mid-1970's stimulated by population growth, general business expansion, and rising per capita consumption of paper products. Growing outlays for research and the development of new products also are expected to increase production and employment.

Employment trends for individual paper and paper products industry groups are expected to differ significantly because of differences in levels of demand and in the impact of technological developments. For example, although output in establishments producing paperboard containers and boxes is expected to increase rapidly, requirements in these establishments should rise only moderately because of rapid increases in output per worker. Output will be spurred by the development of new products and the application of existing products to new markets. For example, a new technique has recently been developed for laminating kraft paper to very thin sheets of steel, which could be used for folding cartons and corrugated shipping containers. The recently developed fiber-foil can, currently widely used for such products as motor oil and frozen fruit juices, is another product for which new uses are being found.

Employment in establishments producing various types of converted paper products is expected to increase moderately. The development of new paper products, including combinations of paper with plastics and metals, should continue to stimulate industrial and consumer demand. Examples of new paper products recently introduced, or to be introduced shortly, include industrial wipes, disposable liquid containers, stretchable grocery and refuse bags, paper tents and sleeping bags, improved paper textiles and clothing for men and women, and even special types of coated paper for use in space vehicles.

In contrast, employment in establishments producing pulp, paper, paperboard, and building paper and board is expected to increase only

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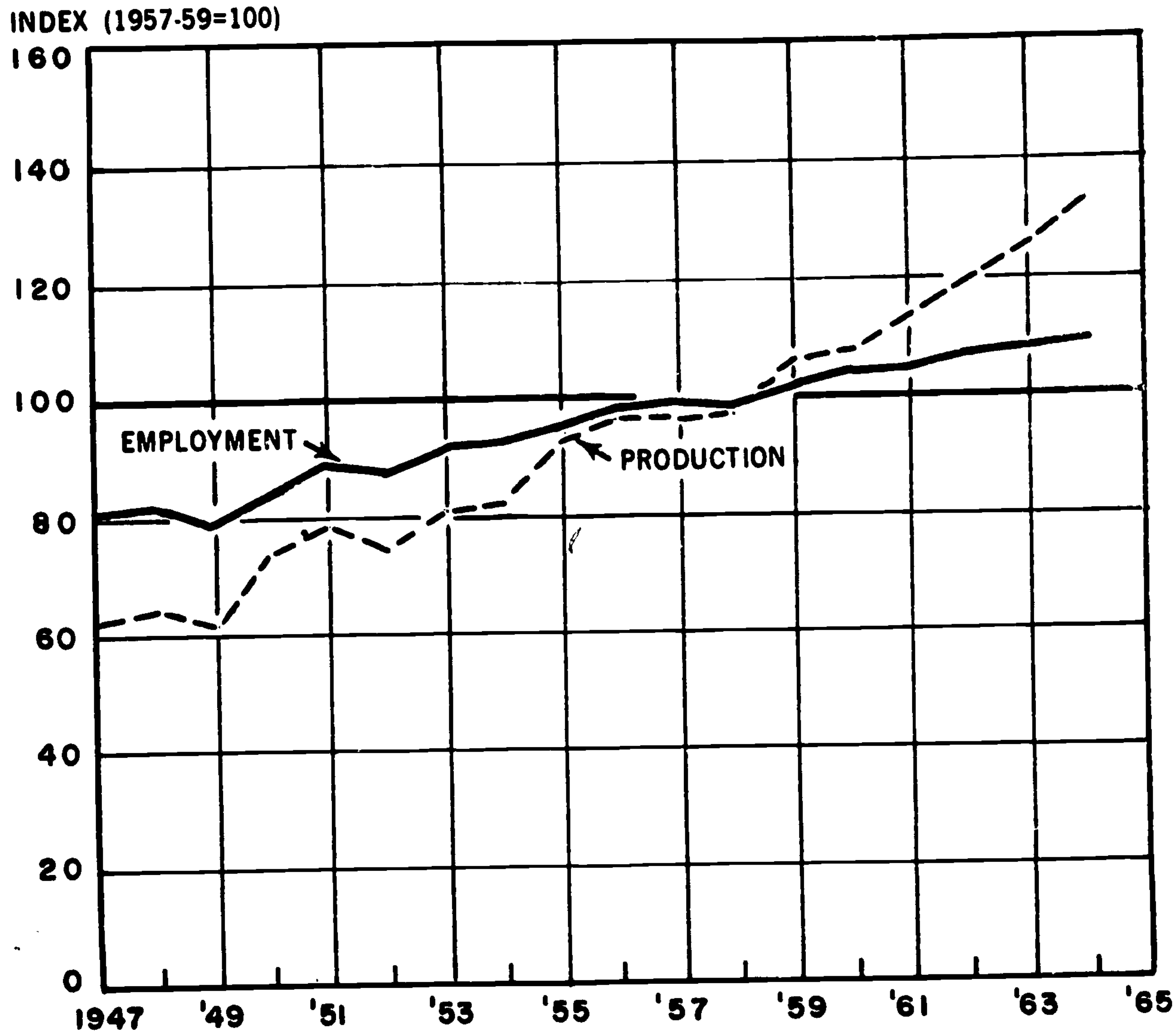
[12] BLS employment (payroll) data for two industry groups—paperboard mills, and converted paper and paperboard products, except containers and boxes—are not available for years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN PAPER AND ALLIED PRODUCTS, 1947-64

Employment (in 000's)	
1947	465
1948	473
1949	455
1950	485
1951	511
1952	504
1953	530
1954	531
1955	550
1956	568
1957	571
1958	564
1959	587
1960	601
1961	601
1962	614
1963	619
1964	625



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

slightly through the mid-1970's as the rising demand for paper—including such basic, heavy-tonnage items as printing and fine papers for use in books, periodicals, and other printed products—is nearly offset by increasing output per worker resulting from growing mechanization and automation of the industry's production processes.

Effects of Technological Developments on Future Employment

Technological innovations are expected to have a significant effect on the number and characteristics of jobs in this major industry group through the mid-1970's. Laborsaving technological innovations will have a particularly significant impact on employment requirements in the pulp, paper, and paperboard industry groups. For example, the use of huge continuous digesters that utilize a steady flow of chips provides easier removal of chemicals and washing liquors and, with the aid of electronic controls such as the magnetic flowmeter, delivers a steady flow of uniform pulp of high-fiber content. The increasing conversion to continuous pulping will change not only the characteristics of jobs such as digester operator, but probably will decrease the number of workers required in pulping operations. In addition, in the conversion of pulp into paper and paperboard, technological advances will continue to increase paper machine widths and speeds, and continued expansion in the use of the trailing blade coater will increase production speed and improve the quality of coated papers. Such developments are increasing employment requirements for highly skilled maintenance and repair workers responsible for keeping this complex equipment in good working order and limiting growth in the requirements for paper machine operating crews.

Pulp and paper manufacturers are placing increasing emphasis on automatic quality control through instrumentation. The trend in instrumentation is toward centralized control systems that allow a few workers to monitor and control production processes. New electronic instruments are being used increasingly. For example, the radioisotope (beta) gage is being used on paper machines to measure and control the "basis weight" of paper and paperboard, and the thickness of coated, laminated, and impregnated paper products. In addition, high-speed computers are coming into limited use for controlling the continuous digester and the paper machine. A computer makes possible better control of operations through rapid collection and analysis of production data, such as type and moisture of wood chips, alkali ratio, and retention time at cooking temperature in pulping operations; and consistency and flow of feed stock, water removal rate, and drying temperatures in papermaking. Computer control of the paper machine can accelerate grade changes and prevent breaks in the web, while providing optimum use of input materials and greater machine productivity. Thus, expansion in the application of instruments and computers should reduce traditional operator requirements while boosting the need for engineers, technicians, personnel trained in the operation of computers and peripheral equipment, and maintenance and repair workers, such as instrument repairmen.

In the converted paper products and the paperboard containers and boxes industry groups, requirements for workers such as hand-feed machine operators and materials handlers and packers will continue to be affected adversely by the growing use of automatic packaging machines; conveyor systems; multioperation cutting, creasing, and stripping machines; multioperation printing and folding machines; palletizing; and mechanized baling operations. On the other hand, the trend toward printing on containers at the converting establishments should increase requirements for printing craftsmen and workers in related occupations.

Printing, Publishing, and Allied Industries (SIC 27)

Summary

Employment requirements in the printing, publishing, and allied industries are expected to increase moderately between 1964 and 1975. Although the increasing use of both automated and more highly mechanized production equipment will limit employment growth in this major industry group, employment is still expected to increase faster than in manufacturing as a whole.

Employment Trends

1947–64. Employment in this major industry group increased from 721,000 to 951,000 between 1947 and 1964, a gain, of almost one-third.

In 1964, over a third of all the workers in this major industry group were employed in the newspaper industry group. Nearly a third were employed in the commercial printing industry group, which includes establishments using lithographic, letterpress, or gravure equipment. The remaining employees were in the following industries: periodical printing and publishing (7 percent); book printing and publishing (8 percent); bookbinding and related industries (5 percent); and other printing and publishing industries (12 percent), which includes service industries to the trade.

Between 1947 and 1964, employment growth among the segments comprising this major industry group varied, reflecting differences in production increases, changes in production processes, and the rate of introduction of highly mechanized and automated equipment. Employment growth was most rapid (89 percent) in the lithographic segment of the commercial printing industry. The introduction of longer lasting printing plates, and faster web offset presses significantly increased the application of this process to large-scale production. The lithographic process is being used increasingly for printing books, periodicals and newspapers. In addition, the lithographic process has several advantages over other printing processes. Using this process, illustrations are of equal or higher quality and less expensive to produce; printing plates can be produced faster; and makeready time on presses is shorter than for letterpress or gravure presses. Employment in the book printing and publishing industry increased by more than 50 percent despite the increasing application of technological laborsaving equipment. This growth in manpower requirements was stimulated by the increasing demand for books by schools, colleges, and by individuals.

Although employment in the newspaper industry increased by 35 percent over the 17-year period, 1947–64, more than three-fourths of this increase occurred prior to 1958. The decline in the rate of employment growth after 1958 reflected the increasing pace of technological change in production equipment, the decrease in the total number of large metropolitan dailies, and the growing practice of many small newspapers to contract out their printing work to larger newspapers or other printing establishments.

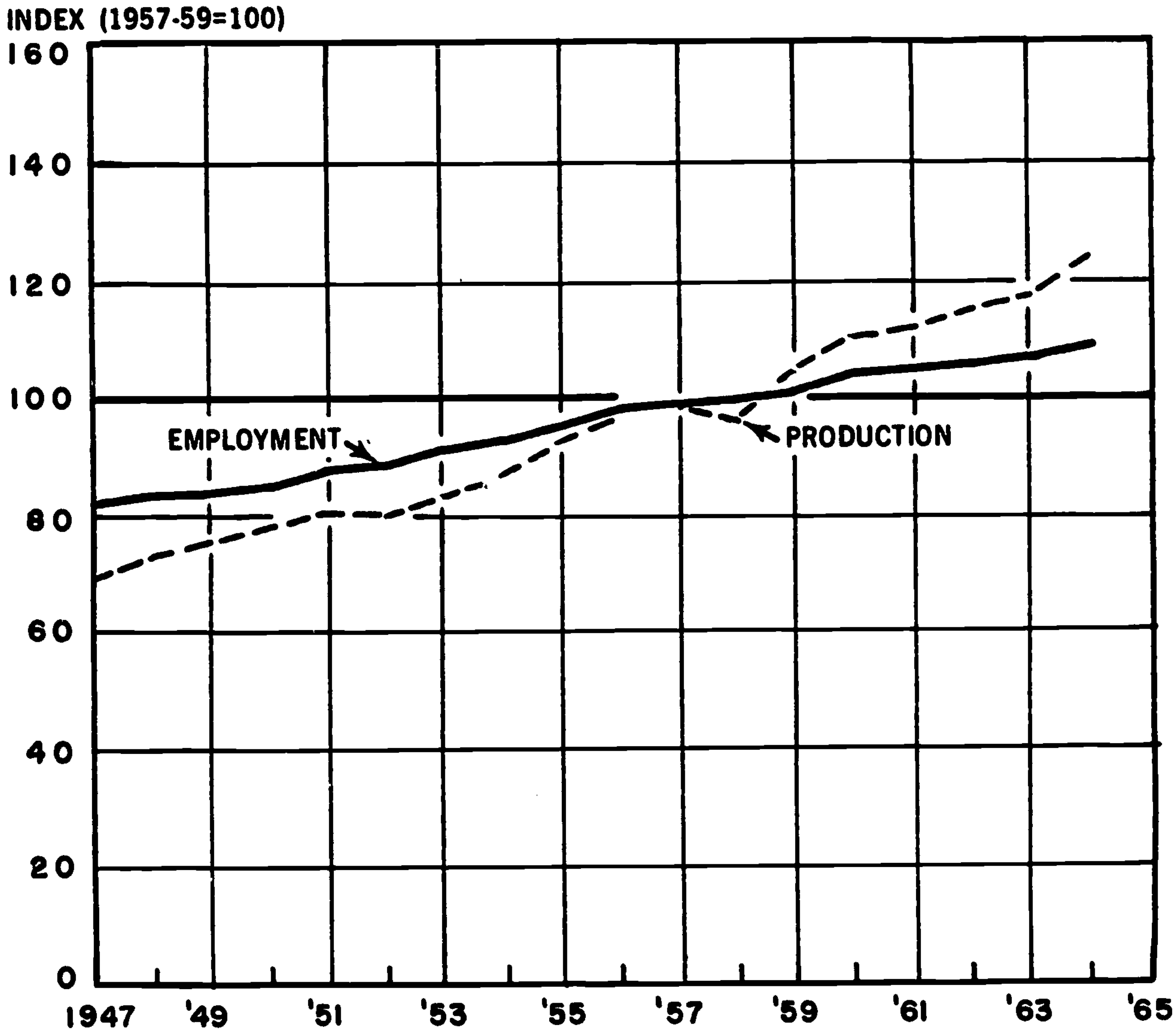
Employment grew least in the periodical publishing and printing industries segment of this major industry group, increasing by only 4 percent over the 1947–64 period, reflecting in part, changes in production methods.

Between 1958 and 1964,[13] employment increased nearly 12 percent in the bookbinding and related

[13] BLS employment (payroll) data are not available for all industry groups for the years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN PRINTING, PUBLISHING, AND ALLIED INDUSTRIES, 1947-64

Employment (in 000's)	
1947	721
1948	740
1949	740
1950	748
1951	768
1952	780
1953	803
1954	814
1955	835
1956	862
1957	870
1958	873
1959	886
1960	911
1961	917
1962	926
1963	931
1964	951



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

industries, despite the increasing mechanization of the production process. This increase reflected the growing demand for books, catalogs, and other materials requiring binding or other finishing operations. Although total employment in other printing and publishing industries increased by 12.5 percent in the 1958–64 period, employment declined in two of the industries in this group. Electrotyping and stereotyping employment decreased by approximately 25 percent as a result of technological changes in platecasting equipment, as well as the increasing use of offset printing, which requires no electrotype or stereotype printing plates. Employment decreased nearly 16 percent in the photoengraving service industry, primarily because of technological changes in photoengraving processes.

1964–75. Employment requirements in this major industry group are expected to increase moderately to about 1.1 million, over the 1964–75 period, despite the increasing use of labor saving technological developments in printing production equipment. Employment of nonproduction workers is expected to increase most rapidly.

Production of printed material is expected to continue to show a substantial growth because of the rapid increase in the school-age population; Federal aid to education; high consumer expenditures for books, periodicals, newspapers, etc.; greater use of prepackaged goods including printed cartons, wrappers, labels, assembly instructions, etc.; the rapidly growing use of various types of business forms; the increasing emphasis on advertising; and the general growth of the economy. Different rates of increase in printing output and in the adoption of laborsaving technological developments will result in different employment trends for individual industries within the major group. For example, manpower requirements in the newspaper industry are not expected to increase and may decline slightly because of the introduction or the increasing use of automatic or highly mechanized equipment including computer-controlled automatic typesetting; the use of photocomposition for newspaper advertising; highly mechanized platecasting equipment; and automated and mechanical equipment in the mailroom, where papers are automatically stacked, counted, and tied in bundles.

The anticipated rapid growth in the demand for printed materials is expected to increase manpower requirements in the book industry and in the bookbinding and related industries. These increases are expected despite the automation of typesetting equipment and the increased mechanization of bindery equipment.

Manpower requirements in this major industry group may be adversely affected by the trend among other industries, such as paper and paperboard converting and baking, to operate "captive" printing shops.

Effects of Technological Developments on Future Employment

Technological developments, primarily in typesetting, platemaking, and in binding and related operations, are expected to have a significant effect on the number and characteristics of printing production jobs, and on the number of apprenticeships that have been characteristic of the skilled printing trades.

Although automated typesetting equipment has been in operation in some plants for a number of years, the rapidly increasing use of such equipment, together with the growth of computer control of the typesetting process is expected to reduce unit labor requirements for typesetting machine operators and tape-perforating machine operators. Automatic typesetting will also reduce the skill requirements for typesetters and the number of apprenticeships in composing room occupations.

The growing utilization of more automatic platecasting equipment, and the increasing use of offset presses in the newspaper industry will continue to reduce the need for stereotypers who produce the duplicate plates used in letterpress printing.

Many technological innovations have been incorporated in finishing processes in the newspaper industry and in the book printing and bookbinding industries, and more extensive use of these processes is expected in the future. These innovations are expected to reduce the need for mailroom employees in the newspaper industry; and the technological innovations in collating, gathering, and binding operations will reduce the need for bindery hands and for bookbinders.

Chemicals and Allied Products (SIC 28)

Summary

Employment requirements in plants manufacturing chemicals and allied products are expected to increase from 877,000 in 1964 to 1.1 million in 1975, an increase of about 25 percent. The increasing application of technological innovations is expected to increase output per worker; however, production is anticipated to increase at a much faster rate than output per worker.

Employment Trends

1947–64. Employment in chemicals manufacturing increased more than three times as rapidly as total manfacturing employment between 1947 and 1964. During the same period, the production of chemicals increased 284 percent as compared with a 100-percent increase in total manufacturing production. In 1947, 649,000 workers were employed in establishments producing chemicals and allied products; by 1964, employment had risen to 877,000 (a rise of about 35 percent), primarily because of a rapid increase in the number of nonproduction workers.

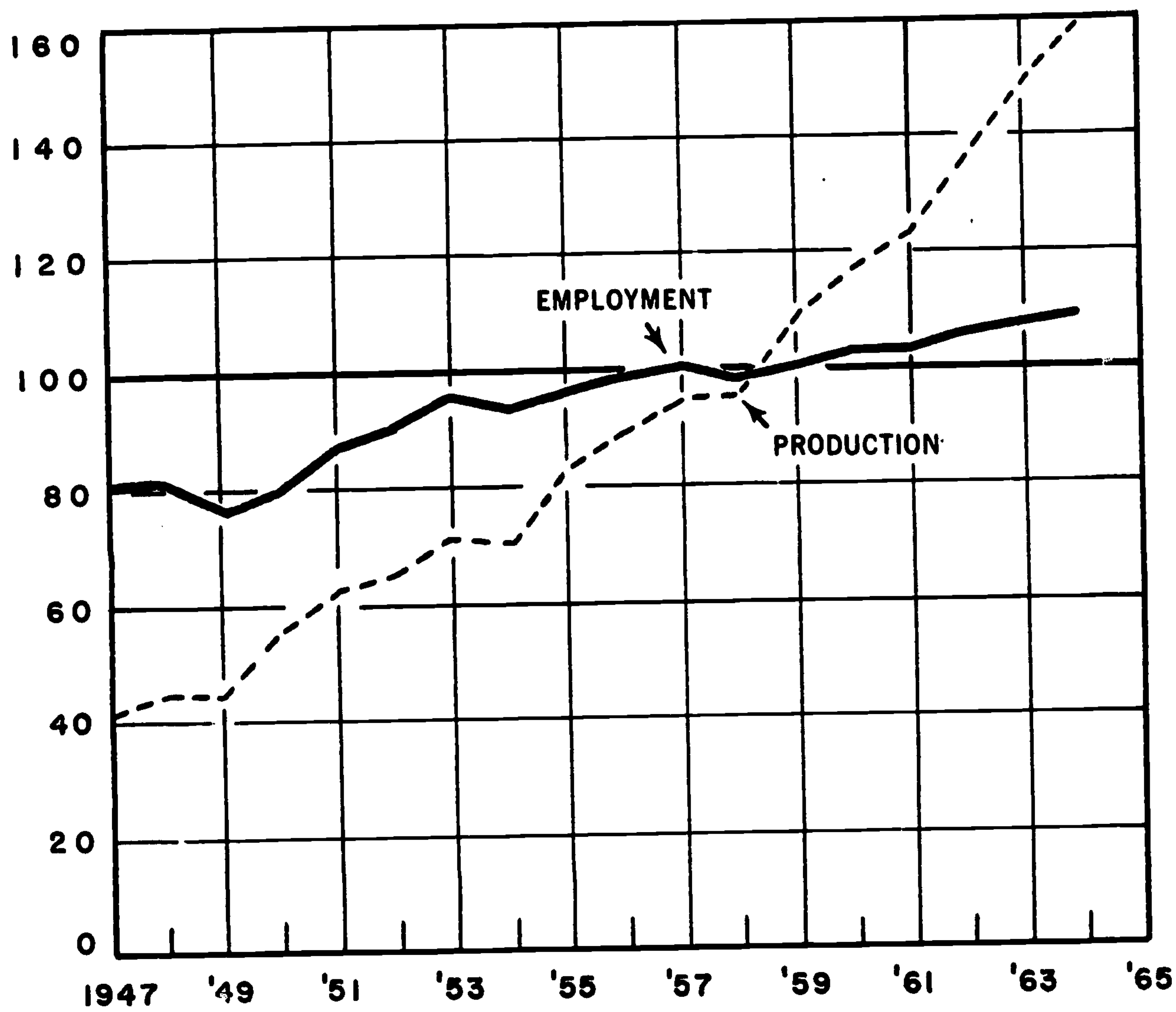
In 1964, nearly a third of total employment in this major industry group was in establishments making industrial inorganic or organic chemicals and about a fifth was in plants producing plastic materials and synthetic resins, synthetic rubber, synthetic and other manmade fibers, except glass. The remaining workers were employed in establishments producing products such as drugs, cleaning preparations, toilet preparations, paints, agricultural chemicals, and gum and wood chemicals.

Although employment in each of the chemical industry groups rose between 1958 and 1964,[14] the rates of growth differed significantly. Employment increased most rapidly (nearly 30 percent) in establishments producing plastics and synthetics, mainly as a result of the development of new plastics and synthetics and new uses for them, including a growing variety of automobile components and textile products. Rises in the number of consumers, in spendable income, and in the variety of products produced also stimulated employment growth in establishments producing soaps, cleaning preparations, and toilet goods. Rapid employment gains in plants producing agricultural chemicals reflected the growing role of fertilizers, pesticides, vitamins, and antibiotics (for farm animals) and other chemicals in modern farming techniques. In contrast, employment rose only slightly in the large industrial chemicals in-

[14] BLS employment (payroll) data for individual chemical industry groups are not available for the years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN CHEMICALS AND ALLIED PRODUCTS, 1947-64

Employment (in 000's)	
1947	649
1948	655
1949	618
1950	640
1951	707
1952	730
1953	768
1954	753
1955	773
1956	797
1957	810
1958	794
1959	809
1960	828
1961	828
1962	849
1963	865
1964	877



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

dustry group, as continuous flow process technology significantly increased output per worker.

The demand for chemicals and allied products has been stimulated in recent years by the tremendous increase in research and development activity, which resulted in many new chemical products such as petrochemicals. Rising R&D activity also contributed to the increase in nonproduction worker employment. In 1963, R&D expenditures by the chemicals industry totaled $1.25 billion—10 percent of all R&D funds expended by industry, and nearly double the amount spent by the major industry group in 1956. It has been reported that more than half of the products now sold by the chemical industry were not in commercial production in 1939. For example, more than 90 percent of the estimated 4,000 drugs and pharmaceuticals being used in the United States today have been developed commercially within the past decade or so.

1964–75. Employment requirements in chemicals manufacturing are expected to increase rapidly in the years ahead. By 1975, employment needs in this industry are expected to reach 1.1 million, approximately one-fourth higher than the 877,000 employed in 1964. The annual rate of employment growth implied by the projection—about 2.2 percent—is slightly faster than the 1947–64 trend in this industry and about 2 times as fast as the anticipated increase in manpower needs in manufacturing as a whole.

The output of chemicals and allied products is expected to be spurred by rising levels of industrial activity, resulting mainly from rising population and personal and corporate income. Rising levels of expenditures for research and development should continue, resulting in new products and markets for chemicals and allied products.

Production and employment is expected to increase especially rapidly in several chemical industry groups. For example, expenditures for drugs are expected to rise sharply in the years ahead, mainly because of rising personal income, health standards, and population, particularly of persons age 55 and over. Also, the drug industry's extensive research and development program may yield a broad range of new products that will stimulate demand, e.g., drugs to combat cancer and heart disease, and new synthetic antibiotics. Demand for plastics is also expected to increase, particularly for new reinforced plastics with new and improved properties for use in building construction, automobiles, housewares, and packaging. In addition, the demand for industrial chemicals, such as acids, salts, and other basic raw materials, will continue to spur production.

Effects of Technological Developments on Future Employment

Technological innovations in the chemical industry are expected to increase output per worker significantly. The increasing use of technological laborsaving devices will be particularly significant in establishments producing industrial chemicals, petrochemicals, and plastics and other synthetics. For example, computers are already being used to direct and control entire production processes, including automatic testing and analysis to ensure optimum quality control. The more widespread use of such equipment is expected to reduce the number of operatives needed for continuous flow production processes and increase requirements for maintenance personnel, such as instrument repairmen. Computers are also being used to chart the quickest and most effective method of overhauling and repairing chemical reactors, and of designing pipe layouts for replacement or plant additions. New lining materials, which are expected to increase the life of chemical reactors and other vessels, thereby reducing day-to-day repair and maintenance, may reduce requirements for vessel maintenance personnel.

Although the "batch" method of production in the drug, paint, dyes, and soap industries is not readily adaptable to widespread automation, technological laborsaving developments are expected in production-related activities. For example, the increasing use of automatic packaging machines, instrumented-conveyor systems, automated-palletizing machines, and computer-controlled shipping devices will continue to displace operatives, material handlers, and shipping and receiving personnel.

Other technological innovations that are expected to be used extensively throughout this major industry group include television monitoring of production processes, radioactive chemical processing, and electronic sensing instruments that replace mechanical testing and measuring devices. The widespread application of increasingly complex production processes requiring extensive instrumentation is expected to increase requirements for technical workers—scientists, engineers, and technicians.

Petroleum Refining and Related Industries (SIC 29)

Summary

Employment requirements in petroleum refining and related industries are expected to continue declining during the 1964–75 period, although at a slower rate than between 1947–64. The employment impact of laborsaving technological developments is expected to be less than during the past 10 years.

Employment Trends

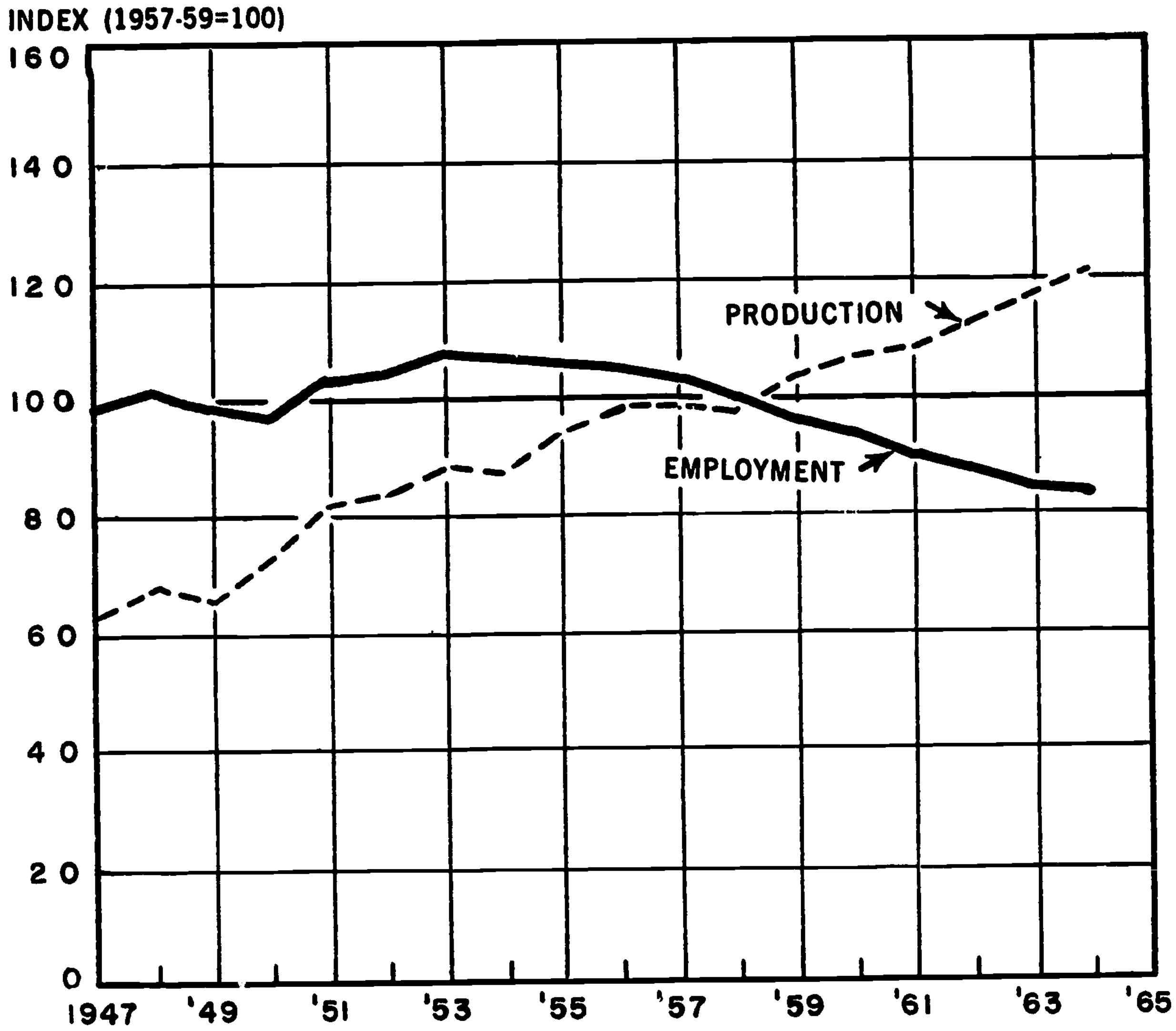
1947–64. Employment in the petroleum refining and related industries major industry group increased 9 percent—from 221,000 to 241,000 workers—between 1947 and 1953; however, during the next 11 years employment declined about 24 percent. The employment decline was primarily in the petroleum refining industry group, which historically has made up over 80 percent of the major industry groups' total employment. In the remaining industry groups—paving and roofing materials and miscellaneous products of petroleum and coal—employment remained relatively stable during the 1958–64 period, with about 34,000 workers.[15] Output per worker increased—especially in petroleum refining—as automation was increasingly applied to production processes. For example, even as employment and the number of operating refineries decreased, between 1953 and 1964, refinery throughput capacity rose 39 percent. Output of petroleum refinery products increased as demand rose for fuel for transportation, heating, and power; lubricants for motor vehicles and industrial machinery; and raw materials for the fast-growing petrochemical industry.

1964–75. Manpower requirements in this major industry group are expected to decline by 13 percent between 1964 and 1975, from 183,000 to 160,000, in spite of significant increases in the produc-

[15] BLS employment (payroll) data for these industry groups are not available for years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN PETROLEUM REFINING AND RELATED INDUSTRIES, 1947-64

Employment (in 000's)	
1947	221
1948	228
1949	221
1950	218
1951	231
1952	235
1953	241
1954	238
1955	237
1956	236
1957	232
1958	224
1959	216
1960	212
1961	202
1962	195
1963	189
1964	183



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

tion of petroleum. The petroleum industry allocates a large part of its financial resources to research and development. Such actvity is expected to continue in the future, resulting in new products and markets for petroleum products and high levels of employment for scientists, engineers, and technicians.

Employment in petroleum refining and related industries is expected to decline at a slower rate through the mid-1970's than between 1953 and 1964, because many automated techniques have already been incorporated into the production processes of this industry—particularly petroleum refining. As a result, future technological advances are expected to improve upon existing processes, to enlarge production capacities, and to create new products. Increases in contract-service maintenance could reduce employment requirements in this industry in the future. In 1962, it was estimated that about 5,500 contract-service workers were performing maintenance in petroleum refineries. These workers were not counted as being employed in the petroleum refining industry.

Although consumption of petroleum is expected to rise substantially during the next decade (some experts estimate as much as 40 percent), the outlook is for fewer, but larger, capacity plants that use highly mechanized techniques and employ relatively few workers.

Effects of Technological Developments on Future Employment

Technological developments in this major industry group during the decade ahead are expected to continue to increase output per worker, particularly in petroleum refining. The continuous flow process is the basic technology underlying the rapid strides this industry has made toward complete automation. Automatic controls and recording and measuring devices have speeded this trend. Operators are no longer needed to open and close valves, adjust liquid flow rates, or control reactor temperatures. A computer-controlled closed-loop system can control, test, record, adjust, and regulate an entire production process automatically. Output per worker is rising through use of refining processes such as hydrocracking, which has increased the return from each barrel of crude oil.

Maintenance, a critical factor in this industry, is also being influenced by technological innovations. Newer, stronger, corrosion-resistant materials are prolonging the periods between turnarounds—major overhauls—thereby reducing the requirements for maintenance workers, usually skilled craftsmen such as pipefitters, boilermakers, and welders. Computers are being used to program turnarounds and to draft layouts for piping systems, thereby reducing unit labor requirements for maintenance workers and draftsmen.

Technological innovations also may change worker skill requirements. For example, operators will need to know the entire production process to be able to correct a process malfunction. Maintenance workers may need multiple craft skills to enable them to work in more than one area. The use of increasingly complex electronic instrumentation will raise skill requirements for instrument repairmen. More trained clerical workers may be needed to operate office machines and other peripheral computer equipment.

Rubber and Miscellaneous Plastics Products (SIC 30)

Summary

Employment requirements in establishments manufacturing rubber and miscellaneous plastics products are expected to increase by about 34 percent between 1964 and 1975. Rising demand for rubber and plastics products should more than offset increases in output per worker.

Employment Trends

1947–64. Employment in rubber and miscellaneous plastics products manufacturing establishments increased about three times as rapidly as in total manufacturing between 1947 and 1964. Workers employed in this industry rose from 323,000 in 1947 to 434,000 in 1964—an increase of one-third. During this period, production nearly tripled; most of this gain was recorded between 1954 and 1964.

Of total workers in this major industry group in 1964, about 23 percent were employed in the tires and inner tubes industry, about 38 percent in other rubber products industries (rubber footwear, reclaimed rubber, and fabricated rubber products, n.e.c.), and about 39 percent in the miscellaneous plastics products industry.

Employment growth has varied among the industries in this major group. During the 1958–64 period,[16] employment rose extremely fast in the miscellaneous plastics products industry (69 percent), rapidly in the other rubber products industries (18 percent), but declined moderately in the tire and inner tube industry (5 percent).

The varied employment growth rates were the results of two significant factors—increased demand for the many and diverse rubber and plastics products and increasing use of laborsaving technological devices in the tire industry. Demand for tires increased steadily, but laborsaving innovations more than offset the rising demand and employment declined. On the other hand, the rapidly rising demand for other rubber and plastics products required many additional workers because of the large and diverse numbers of such products continually being developed.

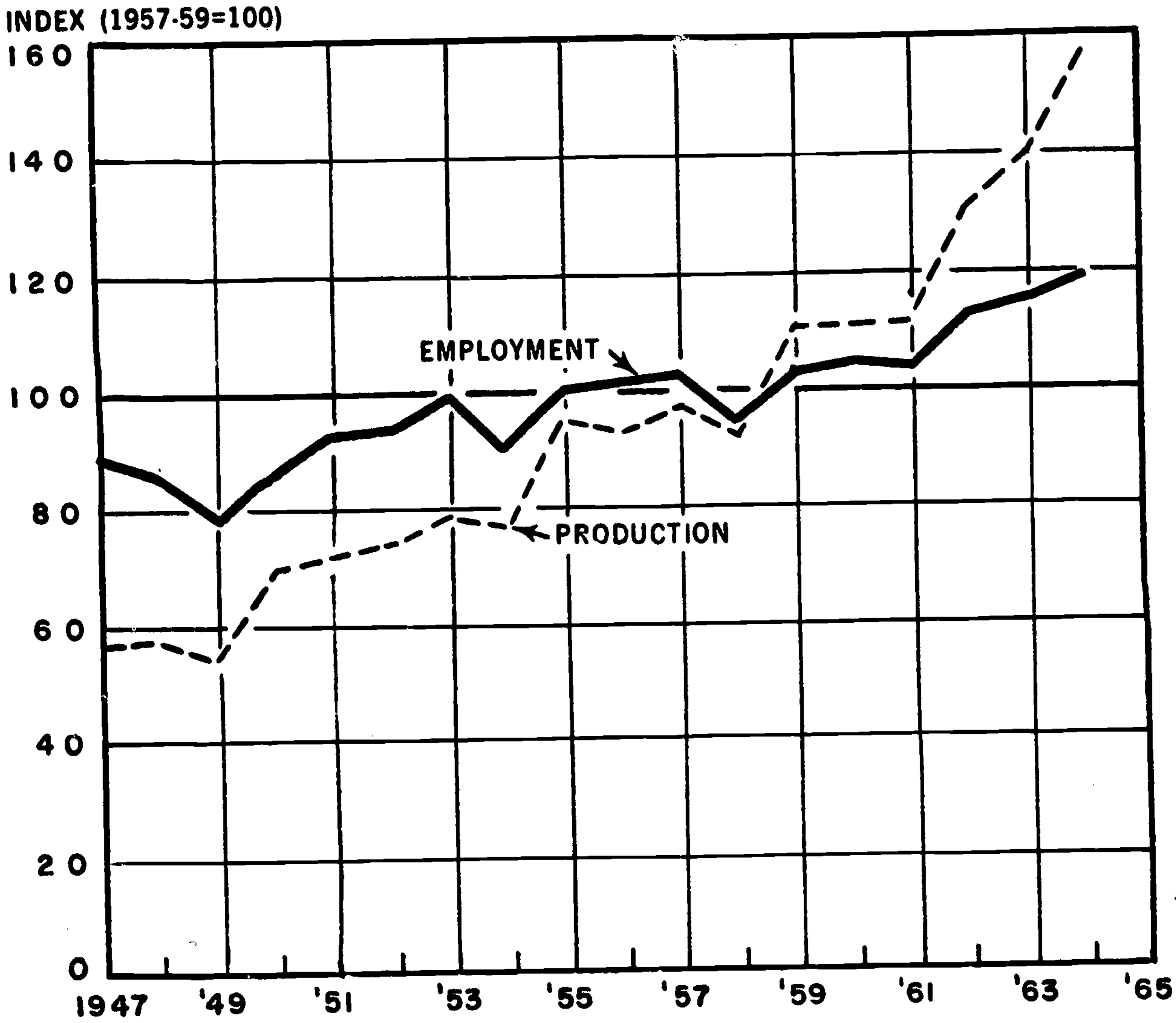
1964–75. Manpower requirements for the rubber and miscellaneous plastics products major industry group are expected to increase very rapidly in the decade ahead. By 1975, employment is expected to reach 580,000, about a 34-percent increase over the 1964 level. The annual rate of growth implied by this projection—2.7 percent—is slower than the 1958–64 rate (3.9 percent), but still almost 2½ times as great as that implied by the projections for total manufacturing. Employment is expected to continue to increase in establishments producing miscellaneous plastics products and rubber products other than tires and inner tubes. Employment in the tire and inner tube industry is expected to show little or no change during the next decade.

In the rubber products industries, other than tires and inner tubes, such items as footwear, drug and medical sundries, wire and cable coatings, and foam rubber are expected to continue in high demand. The relatively low demand for many products makes the introduction of laborsaving technological innovations difficult in most establishments manufacturing rubber products other than tires and inner tubes; therefore, manpower levels are expected to increase in such establishments. Demand is expected to rise fastest for the products of the miscellaneous plastics industry resulting from the rapid growth of construction, transportation, appliances, packaging, general industrial applications, and consumer products. Government-sponsored aerospace activities are expected to spur additional demand for plastics products. As more uses for plastics products continue

[16] BLS employment (payroll) data for the other rubber products industry are not available for years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN RUBBER AND MISCELLANEOUS PLASTICS PRODUCTS, 1947-64

Employment (in 000's)	
1947	323
1948	312
1949	283
1950	311
1951	334
1952	338
1953	361
1954	328
1955	363
1956	369
1957	372
1958	344
1959	373
1960	379
1961	375
1962	408
1963	419
1964	434



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

to be found, manpower requirements will continue increasing. Demand for tires and inner tubes, which accounted for 63 percent of all new rubber consumption in 1964, will continue to increase. However, increasing mechanization of production processes is expected to slow employment growth in the tire and inner tube industry.

Effects of Technological Developments on Future Employment

Technological developments are expected to continue to affect the level of employment and occupational distribution in the rubber and miscellaneous plastics products establishments. In the tire and inner tube industry, increasing use of automatic and semiautomatic machines, and electronic control equipment in processes such as tire building, and curing are expected to reduce unit-labor requirements for operators. For example, new curing equipment requires one pot heater tender (operator) per five machines, compared to a 1-to-1 ratio on the old machines. Greater reliance on automatic conveyor systems will reduce the need for materials handlers, but increased mechanization is expected to raise requirements for maintenance mechanics and instrument repairmen. Research and development efforts will continue to require large numbers of scientists, engineers, and technicians for future technological advances.

In the rubber products industries, other than tires and tubes, technology has developed a large number of diverse products such as rubber footwear, belts and belting, hose and tubing, floor and wall covering, medical and drug sundries, and toys. Mechanized production systems are being used in some areas such as drug sundries and some facets of footwear production. However, the insufficient volume and the large number of different products manufactured make it difficult to automate many of the production processes in this sector of rubber manufacturing.

In establishments producing miscellaneous plastics products, significant advances have been made in product development. Plastics are being developed to replace many materials such as metal, wood, glass, and leather. In most cases, these new plastics products can be fabricated more easily and economically than with conventional materials. Production processes in plastics manufacturing establishments already include mass production methods of molding, casting, and extrusion; therefore, the anticipated increases in demand are expected to be met by enlarging production capacities—new plants or additions—and hiring more operators and related plant workers. As in the past, the emphasis of research and technological development is expected to be in product adaptability and substitution, which will continue to require large numbers of scientists, engineers, and technicians.

Leather and Leather Products (SIC 31)

Summary

Employment in leather and leather products manufacturing establishments, which declined moderately between 1947 and 1964, is expected to remain close to 1964 levels through the mid-1970's. Laborsaving technological developments, and competition from rubber footwear and foreign shoe imports are expected to be significant factors in limiting labor requirements despite increasing demand for domestic nonrubber footwear.

Employment Trends

1947–64. Employment in this major industry group declined from 412,000 in 1947 to about 348,000 in 1964, a decline of about 16 percent.

In 1964, about three-quarters of total leather and leather products employment was in two industries—footwear (except rubber), and handbags and other personal leather goods. The remaining workers were employed in the following industries: Leather tanning and finishing; industrial leather belting and packing; boot and shoe cut stock and findings; leather gloves and mittens; luggage; and other leather goods.

A large proportion of the employment decline in this major industry group between 1947 and 1964 was borne by the leather tanning and finishing industry, where employment fell about 44 percent as manufacturers of shoes and other leather products increasingly substituted manmade materials for leather. The number of workers in the footwear (except rubber) industry declined about 10 percent in the same period, primarily because of the growing importation of shoes (which accounted for almost 10 percent of total U.S. consumption in 1963) and increases in output per worker. Manufacturers were able to reduce labor requirements by making shoes of simpler construction, by using manmade materials, and by using more automatic equipment.

Between 1958 and 1964,[17] employment in the remaining leather and leather products industry groups, combined, was relatively stable.

1964–75. Employment requirements in leather and leather products manufacturing in 1975 are expected to remain at about the same level as in 1964. Domestic production of nonrubber footwear is expected to increase gradually to 1975, although some of the increased demand for footwear generated by an increasing population probably will be supplied by imports. In terms of employment, increasing output per worker is expected to offset the moderate rise in output. More use of manmade materials as substitutes for leather, the development of more uniform leathers, and improved production machinery are the primary factors that are expected to increase production efficiency.

Employment in leather tanning and finishing is expected to continue to decline as mechanization of the processing of hides increases, and manmade materials make further inroads. The industry, however, is finding ways to make a better, more uniform product, and the full effect of manmade materials will be blunted to the extent that this development succeeds.

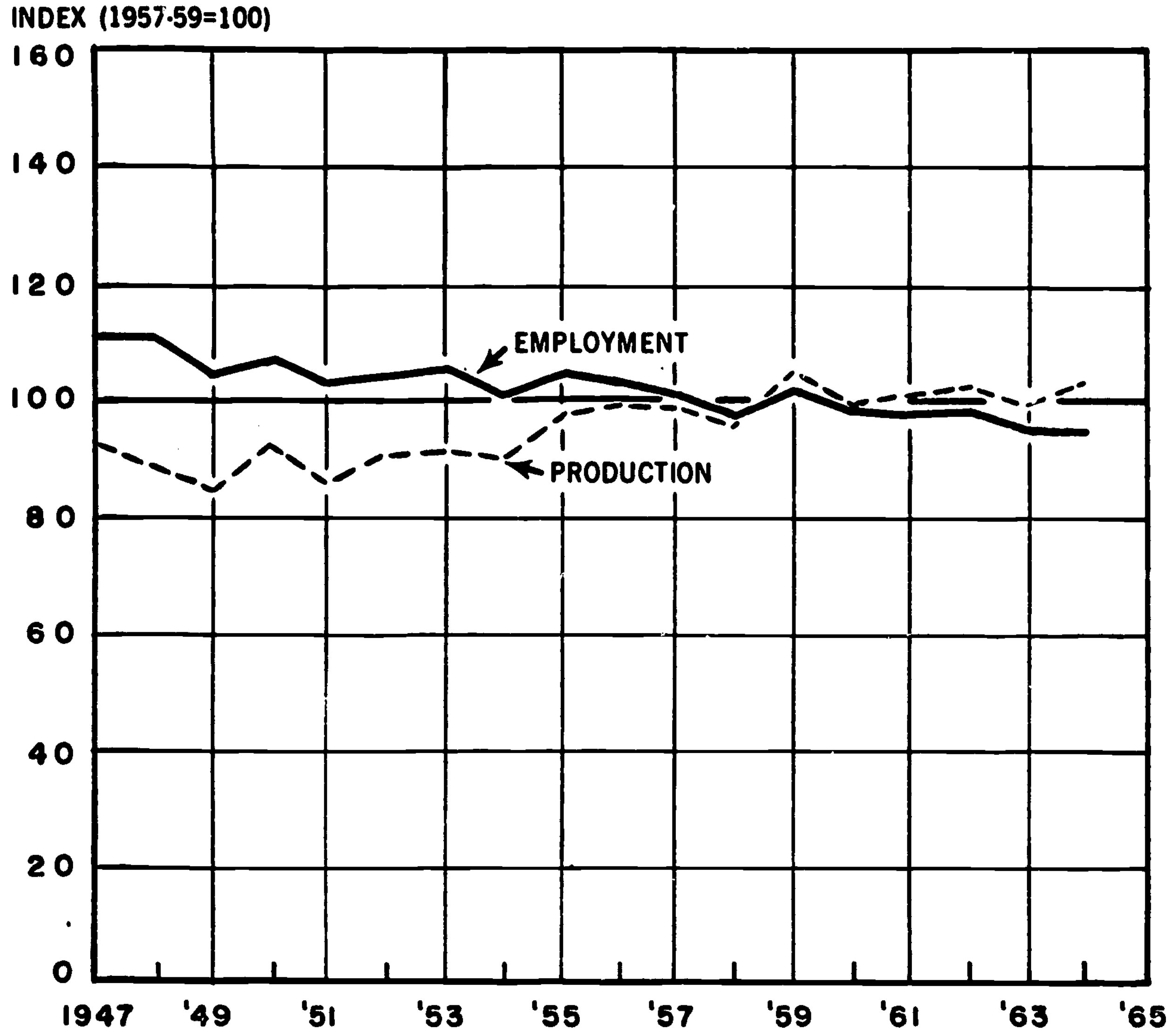
Effects of Technological Developments on Future Employment

In recent years, competition from imports of footwear and from domestic rubber footwear has stimulated U.S. manufacturers of nonrubber footwear to take a much greater interest in new manufacturing techniques and equipment. For example, a new manufacturing process for casual shoes eliminates most traditional shoemaking operations. A line of women's casual shoes, introduced in late 1964, is made by a vacuum-forming process that shapes and forms the shoe so that the bottom and most of the upper is made from a single piece of a specially developed synthetic material. The process eliminates conventional shoe parts including insoles, sock lining, shanks, and box toes, and does not require heel seat and toe lasting.

[17] BLS employment (payroll) data are not available for 6 of the 8 leather and leather products industry groups for the years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN LEATHER AND LEATHER PRODUCTS, 1947-64

Year	Employment (in 000's)
1947	412
1948	412
1949	389
1950	395
1951	380
1952	384
1953	389
1954	373
1955	386
1956	383
1957	373
1958	359
1959	374
1960	363
1961	358
1962	361
1963	349
1964	348



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

The recent introduction of manmade leather substitutes for shoe uppers has made possible the use of more mechanized equipment in shoe manufacturing. These leather substitutes are of uniform quality and can be cut in multiple layers by automatic die-cutting machines, thereby affording significant operating economies. However, even using these new materials, mechanization is not expected to increase rapidly, because of constantly changing styles, variable size runs, and because of the small size of many establishments in the industry. Where manmade materials are used extensively, the need for the skills of the upper-cutting operators may be reduced. To the extent that leather substitutes wear longer than leather, their increasing use may tend to slow sales of shoes.

Research has been underway to develop leather suitable for shoe uppers by breaking down raw hides into their basic fibers and reconstituting them into sheets with uniform properties. Research also has been carried on to develop new finishes for leather to improve its properties. A new method of trimming hides has been developed that would, if used widely by tanning establishments, reduce some processing and handling operations.

The use of more uniform leather and leather substitutes in shoe manufacturing is expected to affect employment requirements adversely for cloth lining cutters, upper cutters, and workers engaged in mulling, treeing, splitting, and skinning. In the long run, the efficiency of lasting operations is expected to be improved. Uniform thickness is expected to encourage the introduction of machines that perform several lasting functions.

New, more efficient, processing methods in bottoming and lasting can be expected to reduce the number of machine operators in these production departments. The use of injection molding machine and vulcanization equipment, which accounted for 15 percent of shoe production in 1964, reportedly eliminates up to 30 traditional shoemaking operations. Thermalasting machinery, which molds a complete synthetic or leather shoe upper to a last and cements the parts together in one operation, combines a large number of previously separate operations, including tacking, stapling, and precementing. Improved heat setting machines cut the time the shoe is on a last from days to hours, greatly reducing the manufacturers' inventory of lasts. The use of conveyors to connect these processes also improves production efficiency. Geometric lasting (based upon the concept of changing all shoe dimensions proportionately with each shoe size change, as opposed to the arithmetic lasting system in general use since 1887) permits the use of highly flexible, automatic equipment, and has great potential for reducing labor needs for adjusting and orienting in shoemaking operations. Another method of lasting introduced recently by a leading shoe manufacturer is based on statistical studies of foot sizes. The firm claims to be able to fit shoes more accurately with a 40 percent reduction in the number of sizes commonly manufactured.

Mechanized materials handling techniques are replacing manual methods in transporting work from one operation to the next, and in warehousing operations. Conveyors are replacing the rack and basket methods of transporting work from one operation to the next. Some conveyor systems can be controlled by means of a console, with one operator directing the flow of work in a complete section, such as a stitching room. A number of firms have recently built modern, one-story plants, especially designed to utilize conveyors in conjunction with other new equipment and processes. Conveyors also are being utilized increasingly for warehouse facilities. One large manufacturer is using computers to control a large conveyorized distribution center that can receive 50,000 pairs of shoes per day and can ship 40,000 pairs to 1,500 dealers in one 8-hour shift, with fewer than 60 employees. This system can handle an inventory of 1.5 million shoes with 49,000 different size and style combinations, and it is being used to distribute the output of 17 production facilities. The increasing use of these improved materials handling systems is expected to reduce requirements for floor boys and girls, elevator operators, and material handlers in warehouses.

Stone, Clay, and Glass Products (SIC 32)

Summary

Employment requirements in the stone, clay, and glass major industry group are expected to increase slightly between 1964 and 1975, but slower than between 1947 and 1964. Technological change is expected to be a significant factor in limiting employment growth.

Employment Trends

1947–64. Employment in this major industry group increased from about 537,000 to 612,000 between 1947 and 1964.

In 1964, more than half of the workers in this major industry group worked in establishments manufacturing clay products including cement, concrete, gypsum, plaster, and pottery. Slightly less than one-fourth of all the workers were in the establishments making glass products, including flat glass, glass containers, and other blown and pressed glass products. The remaining establishments, those producing stone and other nonmetallic minerals products, employed about one-fifth of the workers.

Between 1958 and 1964,[18] employment growth among these three broad segments of the major industry group differed, reflecting differences in the increase in product demand and the rate of introduction of laborsaving technology. Employment increased most (13 percent) in establishments producing glass products to meet the increasing demand for this industry's products, particularly glass containers and flat (sheet) glass.

Despite the increasing application of laborsaving equipment, employment grew in industries producing clay and cut stone and stone products during the 1958–64 period. The number of workers in establishments making clay products rose 6 percent, stimulated by the growing demand for construction materials (cement, concrete, brick, etc.). Employment in establishments producing cut stone and stone products rose 9 percent as output increased rapidly, reflecting the demand by other industrial users for such materials as abrasives, asbestos, and rock-wool insulation.

1964–75. Employment requirements in this major industry group are expected to rise by about 10 percent between 1964 and 1975, to about 675,000. Output is expected to be stimulated by increases in population, new family formations, rising levels of highway and building construction, and expanding manufacturing activity, particularly for motor vehicles.

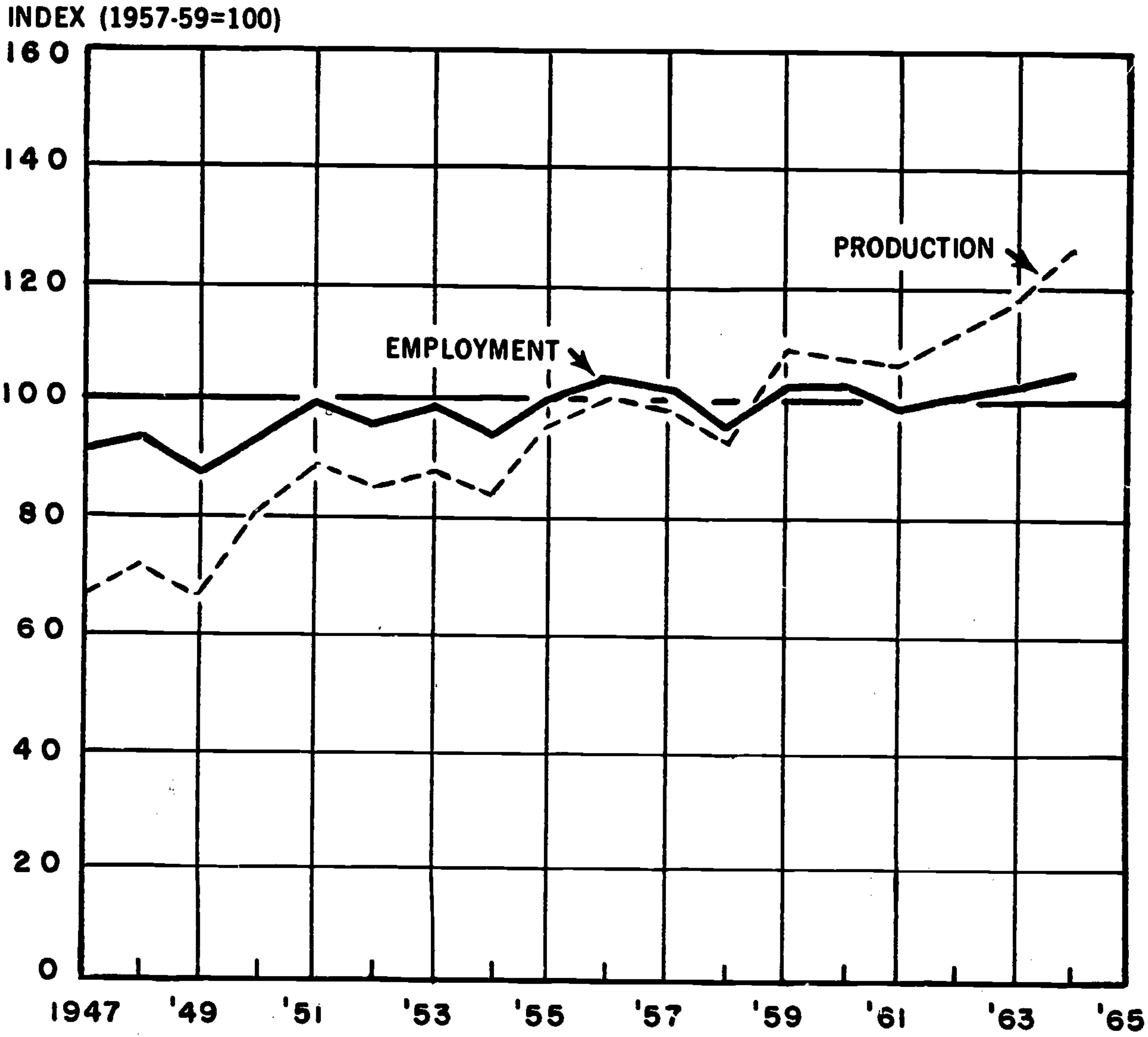
[18] BLS employment (payroll) data by broad segment—clay, stone, and glass—are not available for the years prior to 1958.

Employment trends for the individual industries within the major group are expected to differ widely because of differences in levels of demand and the impact of technological developments. For example, worker requirements in establishments producing glass containers are expected to increase because of a substantial increase in demand. Employment requirements are not expected to be significantly affected by mechanization and other technological innovations because the industry is already highly mechanized. In contrast, employment in establishments making flat glass products is expected to decline despite rising demand, primarily because of the introduction of the "float" process. Labor requirements in establishments producing other pressed or blown glass products are expected to remain relatively unchanged. Although the substitution of plastic materials for these glass products is anticipated, many glass manufacturers are prepared to produce the plastic substitutes.

Employment trends are also expected to vary among industries producing clay products. For example, employment requirements in the hydraulic cement and concrete block industries are expected to remain relatively stable through the next decade. Plants using automatic controls in production processes are expected to account for an increasing proportion of output, resulting in reduced unit manpower needs despite a substantial increase in demand, principally because of rising levels of construction activity. On the other hand, employment requirements in other clay producing industries (those producing gypsum, plaster, lime, and other concrete products) are expected to increase, because of growing demand. The steel industry's requirements for lime, for example, are expected to expand significantly. In the basic oxygen steel-making process (which is expected to increase sharply in the years ahead), more than four times as much lime per ton of steel is required as in the open hearth method. The antici-

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN STONE, CLAY, AND GLASS PRODUCTS, 1947-64

Year	Employment (in 000's)
1947	537
1948	549
1949	514
1950	547
1951	587
1952	564
1953	581
1954	553
1955	588
1956	605
1957	595
1958	562
1959	604
1960	604
1961	582
1962	592
1963	601
1964	612



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board pated increase in home construction activity as the result of new family formations will also stimulate the demand for such products as plaster, plasterboard, brick, clay pipe, and ceramic tile.

Employment requirements in the industries producing cut stone and stone products are expected to remain relatively stable through the mid-1970's as increasing demand for construction related products—insulation, asbestos, etc.—is roughly offset by a drop in demand for abrasive products, resulting from the development of longer lasting abrasive materials as well as product substitution.

Effects of Technological Developments on Future Employment

Technological developments are expected to have a significant effect on the number and characteristics of jobs in this major industry group through the mid-1970's. For example, although the glass products industries are already highly mechanized, recent technological developments are expected to result in improved production equipment and techniques. The use of improved bricklining in furnaces should tend to reduce maintenance requirements, thus the need for bricklayers. The utilization of automatic weighing devices to apportion raw materials is expected to reduce the need for operative personnel. In the production of flat glass, the increasing use of the "float" process will reduce requirements for operators of grinding and polishing equipment. The need for materials handling and packing personnel is expected to be adversely affected by the growing application of automatic conveyor systems, casing machines, and the development of new coating materials that reduce glass breakage. The widespread use of semiautomatic electronic devices to inspect bottles and other glass containers will reduce the need for inspectors. Conversely, the relative importance of instrument mechanics is expected to increase because of the growing instrumentation of production processes.

The growing substitution of plastic for glass is expected to alter materials moving methods and container forming techniques, and could also adversely affect employment in the glass container industry to the extent that production of plastic containers is classified in industries other than glass containers.

Technological innovations in industries producing clay products are expected to continue. Continuous process operations in some plants are now controlled by computers, and more plants are expected to utilize them in the future, thus providing a need for additional personnel trained in the operation of computers and peripheral equipment. A wide variety of instruments are now used in the operation of mixing equipment, weighing devices, kilns, loading and unloading racks, and other equipment; greater use should boost requirements for instrument mechanics, but reduce the need for operators. Requirements for other types of repairmen should rise with the growing use of mechanized materials handling equipment and television monitoring systems. However, the greater use of this equipment will probably reduce the need for materials handling and operative personnel. Rotary hearth kilns and petrotherm heating systems, now used in only a few establishments, are expected to be used increasingly, resulting in greater furnace efficiency and a reduction in maintenance requirements. The adverse effects of laborsaving technology will be partially offset by the increasing demand for new and improved clay products, for example, prestressed concrete and concrete with additives to control shrinkage and to provide greater resilience.

The increasing application of ceramic materials to developments in the fields of aerospace and atomic energy are expected to result in growing requirements for scientists and engineers in research and development activities.

Primary Metals Industries (SIC 33)

Summary

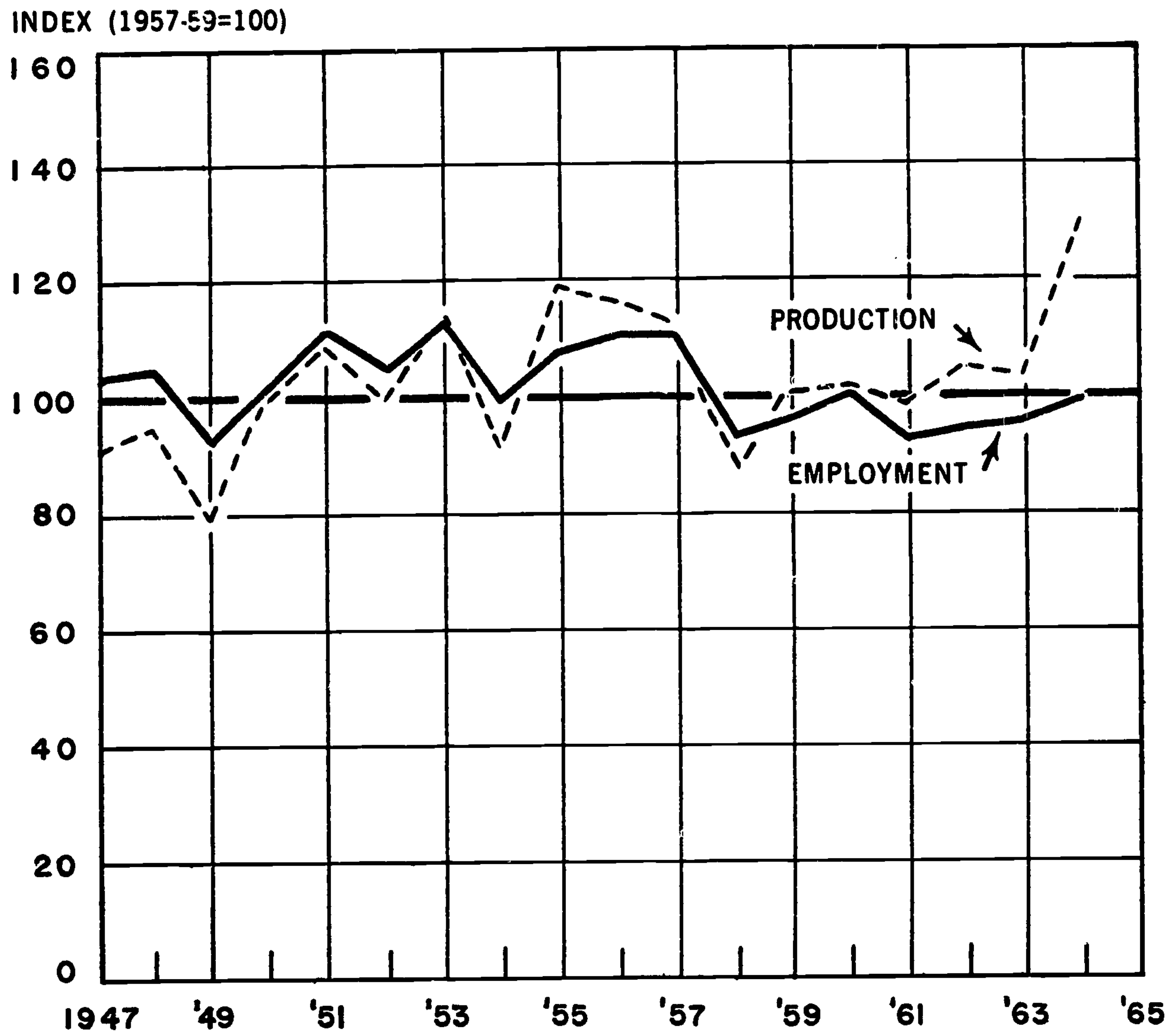
Employment requirements in the primary metals industries are expected to increase slightly between 1964 and 1975, contrasted with a slight decline between 1947 and 1964. The continuing introduction of laborsaving technological innovations and organizational improvements are expected partially to offset the anticipated increase in production, thus limiting manpower requirements in these industries through the mid-1970's.

Employment Trends

1947–64. Total employment in this major industry group declined from about 1.3 million to slightly more than 1.2 million between 1947 and 1964, a decline of about 4 percent. In contrast, total employment in all manufacturing increased by 11 percent over the period. Employment and output in the primary metals industries major industry group fluctuates widely with general business conditions and the demand for capital goods.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN PRIMARY METALS, 1947-64

Employment (in 000's)	
1947	1,279
1948	1,290
1949	1,134
1950	1,247
1951	1,364
1952	1,282
1953	1,383
1954	1,219
1955	1,323
1956	1,355
1957	1,355
1958	1,154
1959	1,183
1960	1,231
1961	1,143
1962	1,166
1963	1,172
1964	1,231



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board.

Between 1947 and 1958 primary metals employment fluctuated between 1.1 and 1.4 million. Since 1958 it has stabilized around 1.2 million. Production worker employment declined at a faster rate than total employment over the 17-year period, falling from slightly more than 1.1 million in 1947 to about 1 million in 1964. Employment of production workers reached its lowest level in 1961—slightly more than 900,000—and then rose steadily through 1964.

The primary metals industries include six industry groups. Two are ferrous, three are nonferrous, and one includes both ferrous and nonferrous establishments. In 1964, more than two-thirds of the total employment in this major industry group was concentrated in two industry groups manufacturing iron and steel: (1) Blast furnaces, steel works, and rolling and finishing mills, which employed about one-half of all workers; and (2) iron and steel foundries, which represented another 17 percent. The nonferrous industry groups include: Smelting and refining of nonferrous metals; rolling, drawing, and extruding of nonferrous metals; and nonferrous foundries. These industries employed about 27 percent of the workers. The remaining workers, about 5 percent, were employed in establishments producing miscellaneous primary metal products, including both ferrous and nonferrous forgings.

Although employment in both the ferrous and nonferrous segments of the major industry group rose between 1958 and 1964,[19] the rates of growth have differed, primarily reflecting differences in the rates of increase in production and introduction of laborsaving technology. Employment increased most rapidly (about 9 percent) in nonferrous industries, while output increased by about 51 percent. Employment increased by only 6 percent in the iron and steel industries, but output increased from its 1958 recession low by more than 45 percent, partly as a result of laborsaving technological developments such as the basic oxygen

[19] BLS employment (payroll) data for most nonferrous industry groups are not available for years prior to 1958.

furnace, improvements in the preparation of raw materials, organizational improvements, and the tendency for production to increase faster than employment after a recession. Output per employee has also increased in nonferrous industries although slower than in the iron and steel industries. The increased output per employee in the nonferrous industries has resulted from improvements in conventional production methods, technological developments such as continuous casting of aluminum, improved worker training, and a variety of other factors.

Increased demand for steel and steel products can be traced to the high levels of production by the major users of steel—the automotive, construction, machinery, and container industries. More favorable depreciation guidelines and the tax credit for new investments has spurred capital goods expenditures, a basic market for steel. In addition, stepped up research and development activities and, in recent years, a substantial, industry-wide sales promotion program has contributed to the increased production of steel. Increased production of copper and copper products has resulted from growth in construction, transportation, electric power distribution, coinage, and a wide variety of producer and consumer durable goods. Research, development of new products, and active promotional activities have been important factors in the growth in demand for aluminum; since 1952, the growth rate has been about double that of industrial production. Aluminum has also become competitive to a limited extent in some of steel's traditional markets. The building and construction, transportation equipment, container and packaging, and consumer durable goods industries have increased their consumption of aluminum relative to other metals. However, for many uses, the various ferrous and nonferrous metals are in active competition with each other and with materials such as plastic, cement, and plywood. Growing population levels and rising levels of disposable income have stimulated the demand for metal consumer durables, including automobiles and household appliances. There has been an increased demand for highways, commercial and industrial construction, and producers durable equipment such as machinery, all of which require large amounts of primary metals.

1964–75. Despite the substantial increase anticipated in output, total manpower requirements in the primary metals industries are expected to increase only slightly in the years ahead, even assuming a slight reduction in imports of steel. By 1975, employment needs might reach almost 1.3 million, less than 5 percent above the 1964 employment level. Output of metal consumer durables is expected to increase during the next decade in response to growth in the population and rising levels of disposable income. Output is also expected to be stimulated by an increased demand for housing, factories, office buildings, highways, and producers durable equipment such as machinery.

Employment trends for ferrous and nonferrous industry groups are expected to differ widely because of differences in levels of demand and the impact of technological developments. For example, manpower requirements in nonferrous foundries are expected to increase rapidly because of a substantial increase in the demand for nonferrous (especially aluminum) castings. Production of aluminum castings is expected to grow rapidly because aluminum is used increasingly in a wide range of new products. In contrast, little employment growth is expected in establishments producing and casting iron and steel, which accounted for over two-thirds of total primary metals employment in 1964. The growing use of electronic data processing and communications equipment is expected to result in increased efficiency in office operations, particularly in basic iron and steel establishments. Continued increases in output per production worker are expected to result from increasing use of the basic oxygen furnace and the continuous casting process; greater use of oxygen in blast furnaces and open hearth furnaces; continued mechanization of materials handling operations; and the greater use of instruments to control production, especially in rolling mills, in tin coating processes, and in heating and controlling furnaces. However, the growing industrial demand for higher quality steel may act as a slight restraint on future increases in output per worker.

Manpower requirements in the remainder of the major industry group are expected to increase slightly between 1964 and 1975. Continued mechanization of materials handling is expected to be one of the major factors in limiting manpower requirements in these industries.

Effects of Technological Developments on Future Employment

Technological developments are expected to have a significant effect on the number and characteristics of jobs in this major industry group through the mid-1970's. Developments in iron and steel industries have formed a significant part of the changing technology in the primary metals major industry group. Important innovations include the basic oxygen furnace, and the continuous casting process. The basic oxygen furnace had become the second most important steelmaking process in the United States in 1964 (exceeded only by the open-hearth process) and its importance is expected to continue to grow through the mid-1970's. Continuing improvements in the basic oxygen process suggest a rapid growth. The basic oxygen furnace can now reduce pig iron to steel four to six times faster than the open hearth. In addition, capital and operating costs are substantially lower than such costs in conventional open-hearth operations.

The increased use of the basic oxygen furnace and the use of oxygen lances in blast furnaces and open-hearths is expected to increase the need for engineers and scientists needed to develop mathematical models and pilot studies in order to obtain the optimum benefits from the new and improved techniques. Conversely, the relative importance of operatives is expected to decrease because the greater speed of the basic oxygen process enables a given amount of steel to be made with fewer furnaces. These developments may reduce the skill requirements of some of the remaining employees, for example, the operator of the basic oxygen furnace may be less skilled than the operator of an open-hearth furnace. In addition, improvements in refactories used in blast furnaces and steelmaking furnaces are expected to increase the lives of furnace linings substantially, thus lowering the requirements for brickmasons.

One of the latest developments in steelmaking is the continuous casting process, which converts molten steel directly into semifinished shapes, eliminating some of the steps used in the conventional process. Greater use of the continuous casting method is expected to increase the need for scientists and engineers, reduce the relative importance of certain skilled occupations such as rollers and roll hands, and reduce the relative importance of cranemen who are used to transfer molten steel to the ingot molds and workers who remove the molds from the steel, move ingots to and from soaking pits and reduce ingots in size in the blooming, roughing and slabbing mills.

Increased mechanization and instrumentation has increased speeds of conventional finishing mills, and made possible closer tolerances in rolling and more uniformity in products. Innovations in instrumentation are anticipated because of the great adaptability of basic oxygen steelmaking and continuous casting to automatic control. Greater instrumentation is expected to increase the relative importance of instrument repairmen in the major industry group.

Improvements in existing facilities have resulted in greater efficiency in conventional production methods used in the nonferrous segments of the major industry group. Major areas of change include larger ingots, faster rolling rates, and increased use of electronic controls. These developments have tended to reduce the relative importance of operatives and some craftsmen such as rollers and roll hands.

Continuing improvements in foundry technology are expected to lead to substantial increases in output per employee. For example, the increased mechanization of coremaking operations could reduce the relative importance of coremakers. Unit labor requirements for materials handling and packing personnel is expected to be reduced by the introduction and increased use of materials handling equipment in all industries within the major industry group.

Fabricated Metal Products (SIC 34)

Summary

Employment requirements in the fabricated metal products major industry group are expected to rise faster in the next decade than between 1947 and 1964. Employment requirements are not expected to rise as fast as production because the application of laborsaving technological innovations will increase output per worker.

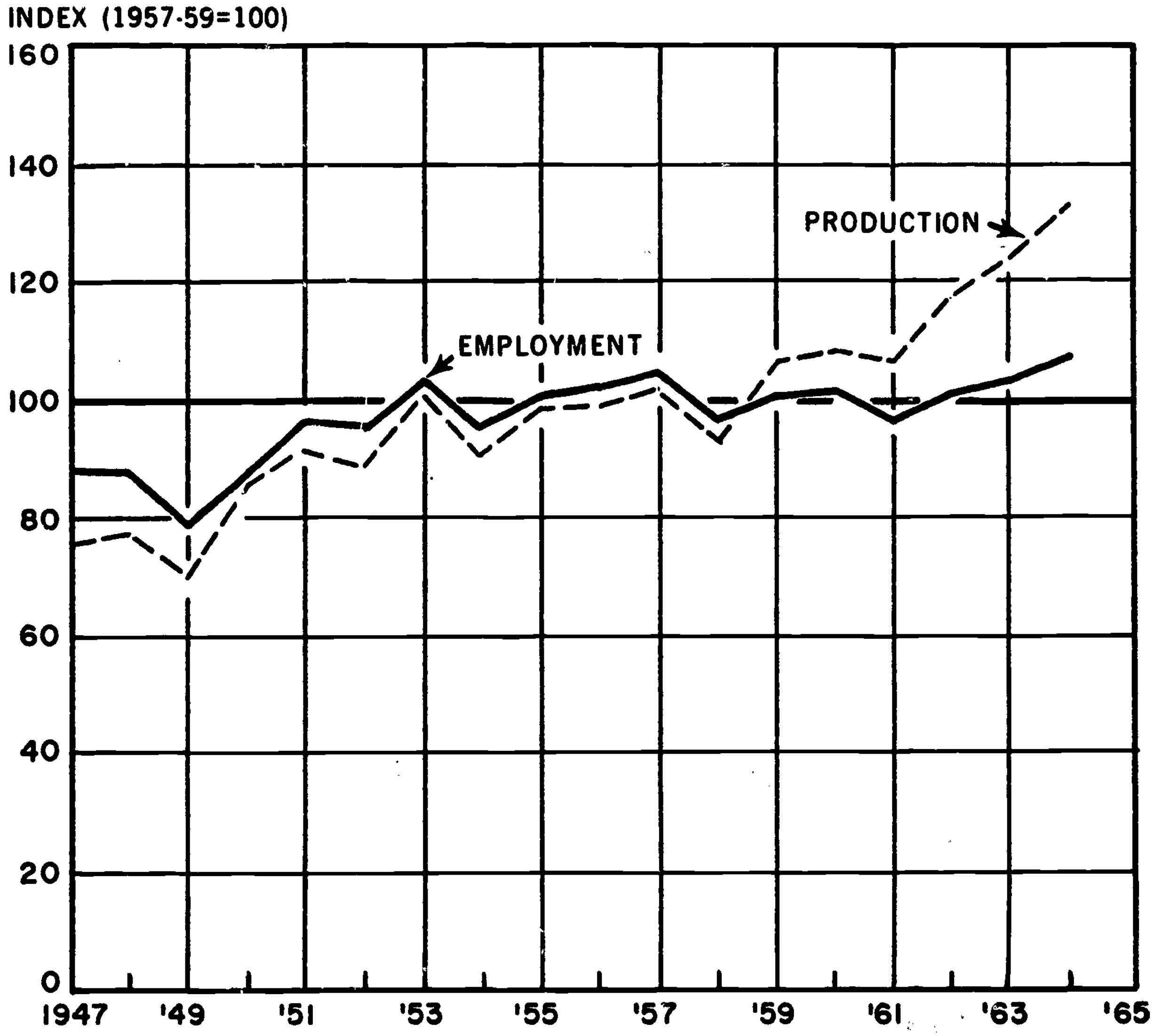
Employment Trends

1947–64. Employment in the fabricated metal products major industry group increased from about 989 thousand to approximately 1.2 million between 1947 and 1964, or 20 percent. During this period, output of fabricated metal products increased mainly because of expanding population, rising levels of personal and corporate income, and increasing construction and manufacturing activity, particularly new nonresidential construction activity and automobile production.

In 1964, almost 30 percent of total employment in the fabricated metal products major industry group was in establishments manufacturing fabricated structural metal products, including fabricated structural steel, metal window and doorframes, power boilers and storage vessels, and architectural and ornamental metalwork. One-sixth of all workers were employed in establishments producing metal stampings. In addition, about 25 percent of all employees worked in establishments making cutlery, handtools, and general hardware, including razor blades, wrenches, saw blades, and transportation equipment and builders hardware; and in establishments producing such miscellaneous fabricated metal products as steel drums and pails, safes and vaults, steel springs, valves and pipe fittings, collapsible tubes, metal foil products, and fabricated

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN FABRICATED METAL PRODUCTS, EXCEPT ORDNANCE, MACHINERY, AND TRANSPORTATION EQUIPMENT, 1947-64

Year	Employment (in 000's)
1947	989
1948	979
1949	881
1950	982
1951	1,078
1952	1,064
1953	1,156
1954	1,070
1955	1,122
1956	1,140
1957	1,167
1958	1,077
1959	1,123
1960	1,135
1961	1,085
1962	1,128
1963	1,150
1964	1,187



Source: Employment, Bureau of Labor Statistics; industrial production, Federal Reserve Board.

pipe. The remaining workers were employed in establishments making screw machine products, and bolts, nuts, screws, rivets, and washers; heating apparatus (except electric) and plumbing fixtures; metal cans; miscellaneous fabricated wire products; and performing coating, engraving, and allied services.

Between 1958[20] and 1964, employment trends differed widely among the fabricated metal products industry groups. For example, employment increased by slightly more than one-quarter in establishments performing coating, engraving, and allied services as demand rose for plated parts, such as bumpers used in transportation equipment. However, employment in establishments producing metal cans remained virtually unchanged, mainly because growth in the demand for cans was limited by competition from fiber-foil, plastic, and glass containers, and by the increasing use of laborsaving technological innovations.

1964–75. Employment requirements in this major industry group are expected to rise to about 1.5 million in 1975, nearly 23 percent above the 1964 level. Although the high levels of economic activity anticipated in the decade ahead will stimulate output of fabricated metal products, employment will increase more slowly because of the growing application of laborsaving technological innovations.

Employment trends in the individual fabricated metal products industry groups are expected to continue to differ widely because of differences in levels of demand and the rates of adoption of

[20] BLS employment (payroll) data for most fabricated metal products industry groups are not available for years prior to 1958.

laborsaving technological innovations. For example, employment requirements in establishments performing coating, plating, and allied services are expected to rise substantially because of rising demand. The production processes used in these establishments are already highly mechanized; consequently, technological developments are not expected to have a significant impact on labor requirements. In contrast, employment requirements in establishments making metal cans are expected to decline slightly despite rising demand, mainly because of improvements in production machinery and procedures that will increase output per worker.

Effects of Technological Developments on Future Employment

Technological developments are expected to be a significant factor in limiting employment growth in this major industry group through the mid-1970's. New and improved industrial machinery is expected to be used increasingly, much of which will be controlled automatically. Greater use of instruments is anticipated for quality control and other operations. The use of automatic transfer and conveyor systems will reduce labor requirements for machine feeding and materials handling. One of the major developments anticipated is the more widespread use of numerically controlled machine tools.

The integration of conventional machine tools with conveyors and mechanical and electronic control devices should result in more automatic processing and handling of work pieces. Such systems are most feasible in establishments producing large quantities of a standardized product, such as razor blades and metal cans; however, the transfer line technique can also be used economically in production operations such as heat treating, welding, forging, and plating. In view of the greater efficiency of automatic transfer equipment, it is expected that manufacturers will install this equipment at a fairly rapid rate throughout the 1965–75 decade, resulting in reduced requirements for machine operators and materials handling laborers.

Numerical control is a major advancement in machining operations. This innovation provides a means of automatically controlling the operation of machine tools by use of electronic devices and changeable tapes on which directions have been punched. This technique is particularly suitable for producing a variety of different metal parts in small volume—the job shop type production typical of many establishments in this major industry group. Reportedly, numerical control not only makes possible substantial reduction in unit labor requirements relative to conventional machine tools, but also provides cost savings through reduced scrap and inventories of jigs and fixtures, and, because of greater accuracy and flexibility, makes feasible production of parts formerly uneconomical or technologically impractical. As of 1963, there were less than 300 numerically controlled machines in use in the industry, but the number is expected to expand substantially through the mid-1970's as the price of these machines continues to decrease and as management becomes more aware of their advantages. In many instances, the use of numerically controlled equipment requires management to assume direct responsibility for such production operations as interpreting engineering drawings, establishing machine setups, determining tooling, and selecting cutting speeds and feeds, a responsibility assumed by operating personnel such as machinists and shop supervisors when conventional tools are used. As a result of these changes, additional engineers and programers may be required to plan and program production operations. However, employment requirements for production and toolroom machinists, machine tool operators, and tool and die makers are expected to be adversely affected.

Machinery, Except Electrical (SIC 35)

Summary

Employment requirements in the machinery, except electrical, major industry group are expected to increase rapidly between 1964 and 1975. However, employment is not expected to increase as rapidly as production because of the increasing application of laborsaving technological innovations.

Employment Trends

1947–64. Employment in the machinery, except electrical, major industry group varied substantially from year to year in its rise from about 1.4 million in 1947 to approximately 1.6 million workers in 1964. During the intervening years relatively high employment occurred in 1953 (1.55 million) and in 1957 (1.59 million). Nonproduction worker employment increased by 70 percent between 1947 and 1964, and rose from 21 to 30 percent of the total. Employment of production workers increased by only 3 percent over the 1947–64 period, reaching its peak in 1953. In 1964, employment of production workers was about 2 percent below the 1953 peak.

The machinery major industry group consists of

9 different industry groups. In 1964, the largest in terms of employment was metalworking machinery, with almost 18 percent of all workers. Slightly more than one-fourth of all workers were in establishments manufacturing special industry machinery or general industrial machinery; 15 percent, in establishments manufacturing construction, mining, and materials handling machinery and equipment; about 11 percent, in establishments manufacturing office, computing, and accounting machines; and the remaining workers were in establishments producing engines and turbines, farm machinery and equipment, service industry machinery, and miscellaneous machinery.

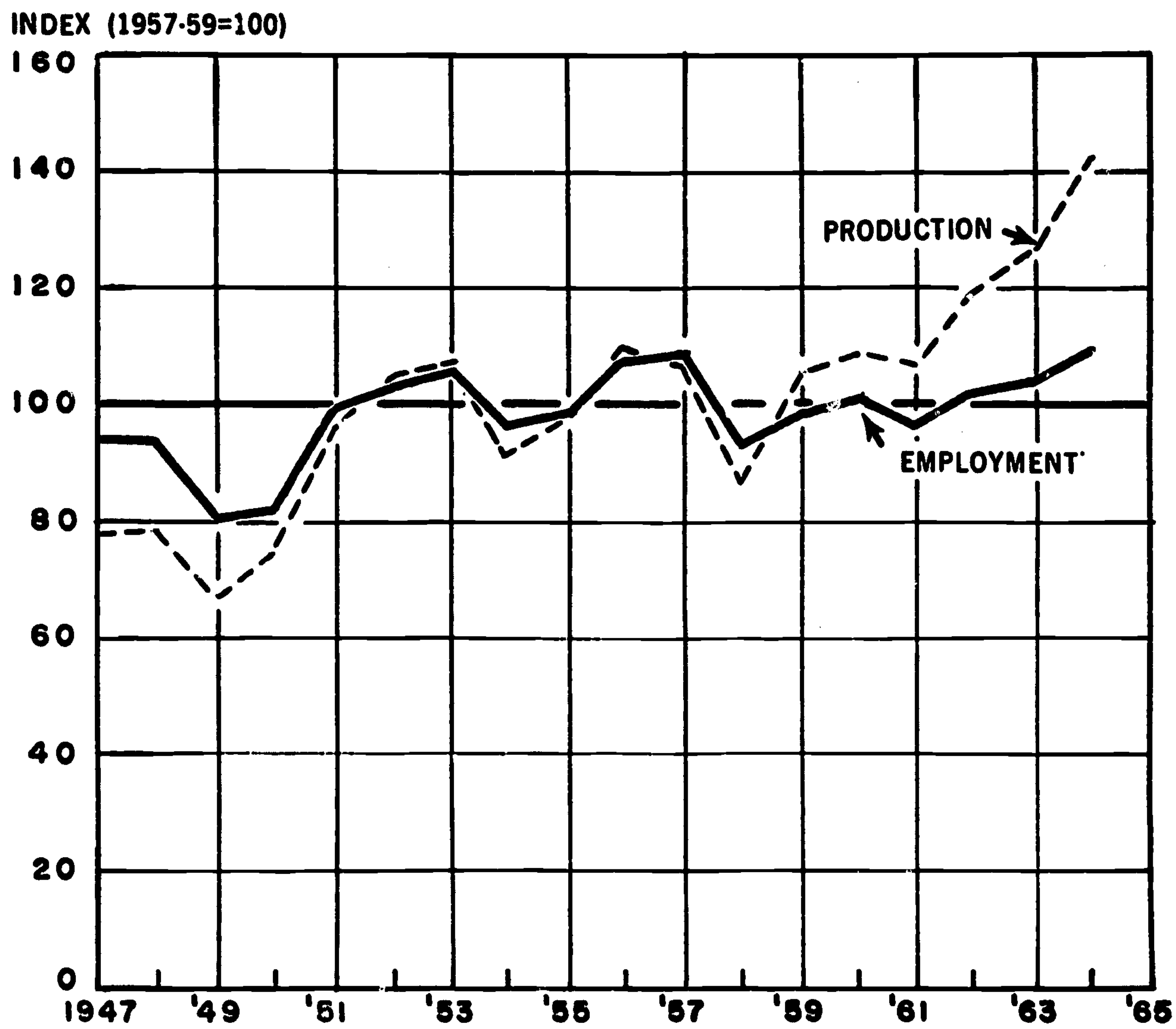
Employment in all but one of the machinery industry groups rose between 1958 and 1964;[21] however, the rates of growth differed widely, reflecting differences in the increases in product demand and the rates of introduction of laborsaving technology. Employment declined in the engines and turbines industry, as the demand declined for products such as navy and marine steam turbines. In contrast, employment increased rapidly (over 30 percent) in the accounting, computing, and office machine industry groups, primarily because of a very rapid increase in the demand for computers. Rapid employment growth also occurred in establishments producing general industry machinery, miscellaneous machinery, and metal working machinery (primarily machine tools). In the latter establishments, employment gains reflected the expansion and modernization of the domestic metalworking industries, particularly the automotive industry, the largest user of machine tools. An upsurge in foreign demand for U.S. machine tools also contributed to increased employment in these establishments.

Employment rose rapidly in establishments producing construction, mining, and materials

[21] BLS employment (payroll) data for most industry groups are not available for the years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN MACHINERY, EXCEPT ELECTRICAL, 1947-64

Employment	(in 000's)
1947	1,375
1948	1,372
1949	1,182
1950	1,210
1951	1,457
1952	1,517
1953	1,554
1954	1,418
1955	1,449
1956	1,572
1957	1,586
1958	1,362
1959	1,452
1960	1,479
1961	1,419
1962	1,493
1963	1,529
1964	1,606



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board handling equipment and machinery, reflecting an increased demand for machinery and equipment used in mining, logging, agriculture, oil fields, land reclamation, irrigation, power and communications systems, and municipal maintenance, as well as in general construction. The increasing use of materials handling equipment in many industries has contributed to employment growth in this industry group. In addition, employment in establishments manufacturing service industry machinery, such as vending machines and dry cleaning equipment, rose rapidly with the general increase in the demand for personal services.

Employment increased moderately in the industry groups manufacturing farm machinery and special industry machinery. In the latter, employment gains reflected the replacement of obsolete equipment and increased demand for the products of direct user industries such as textiles, paper and paper products, and foods. The demand for these products was stimulated by rising levels of population and personal disposable income.

1964–75. Employment requirements in the major industry group are expected to rise by more than one-fourth between 1964 and 1975, to about two million, somewhat faster than during the 1947–64 period. Employment is expected to grow as a result of increasing demand for machinery and related equipment.

Three factors are expected to increase demand for machinery and related equipment. Expenditures for new plant and equipment in general are anticipated to increase rapidly. In addition, a high proportion of machinery currently in use is obsolete and will have to be replaced. As of 1963, for example, 64 percent of the metalcutting machinery in use was at least 10 years old, and 20 percent was more than 20 years old. Also, rules governing depreciation allowances have been changed to allow a more rapid depreciation of new machinery and equipment. Federal tax law changes, which allow income tax credit for new investments in plant and equipment, will also stimulate demand for machinery.

Employment trends for individual industries within the major industry group are expected to differ only slightly because of the differences in levels of demand and the impact of technological developments. For example, worker requirements are expected to increase rapidly in establishments producing special industry machinery, such as food processing machinery, textitle machinery, paper industries machinery, and printing trades machinery. Expanding population and rising levels of personal disposable income will result in a greater demand for food, clothing, and furniture, as well as for paper and paper products. Increasing emphasis on education will raise the demand for books and other printed materials that are produced by special industry machinery manufacturers.

Manpower requirements also are expected to increase rapidly in the machine tool industries. The increasing use of numerically controlled equipment should increase machine tool orders. However, greater demand for numerically controlled equipment may be, at least in part, at the expense of orders for conventional machines.

Employment in the construction, mining, and materials handling machinery and equipment industries is expected to be spurred by rising construction activity to meet the needs of an increasing population. In addition, emphasis on cost-reduction and rationalization of materials movement will increase the need for mechanized materials handling equipment.

Effects of Technological Developments on Future Employment

Increases in output per employee are expected to offset, in part, increases in machinery production through the mid-1970's. Significant developments will include the greater use of numerically controlled machine tools, automatic transfer equipment, production control instruments, and computers that improve production and data processing operations.

Numerical control of machine tools constitutes a key technological development in the evolution of machinery. Previous changes largely involved improvements in power, speed, and specialization of machine tools. Numerical control provides a means of mechanizing control of machine tools by means of electronic devices and changeable tapes on which directions have been punched. It constitutes a technique for reducing labor requirements in machining small lots of metal parts and equipment. The small lot or "job shop" process is characteristic of this major industry group. Numerical control makes it possible to reduce substantially unit labor requirements relative to conventional machine tools. (Examples reportedly include unit labor savings of 25 to 80 percent over conventional methods.) The number of numerically controlled machine tools in use in the major industry group is expected to increase substantially through the mid-1970's. As a result, manpower requirements for machinists, and machine tool operators may be reduced. Conversely, additional engineers, programers, and technicians may be needed.

Use of automatic transfer equipment will grow at a fairly rapid rate in establishments producing large quantities of a standardized product. Transfer machines are multistation machines within which the work piece is automatically moved from station to station. Separate operations are performed at each station. As a general rule, the loading and unloading of the machines, as well as the positioning of the work piece, is automatic. The increased use of such equipment will have an adverse affect on machine tool operators and materials handling laborers, thus reducing the relative importance of these workers.

Increasing reliance will be placed on instrumentation and computer control. Increased instrumentation will tend to lower the relative importance of inspectors and operators, but raise requirements for instrument repairmen. In addition, inventory control and accounting functions may be handled by electronic computers, thus lowering the requirement for some clerical workers.

Employment requirements could be affected by new metal-working processes currently in limited use or under development that remove metal without the use of a cutting tool. The more important techniques include chemical machining, electrolytic machining, electrical discharge machining, electron beam machining, and laser beam machining. The increased use of electrical discharge machinery could, for example, reduce the need for diemakers. However, the use of these techniques is not expected to increase fast enough through the mid-1970's to affect significantly employment requirements.

Electrical Machinery, Equipment, and Supplies (SIC 36)

Summary

Employment requirements in the electrical machinery, equipment, and supplies major industry group are expected to increase very rapidly during the decade ahead. Despite the growing application of laborsaving devices and processes, it is estimated that about 2.0 million workers will be required by 1975 to meet the anticipated rapid growth in demand for the products of this major industry group.

Employment Trends

1947–64. Employment in establishments manufacturing electrical machinery, equipment, and supplies increased from slightly more than 1 million in 1947 to more than 1.5 million in 1964, or about 50 percent. During the same period, production in this major industry group rose 175 percent.

In recent years, employment and output in the industries primarily engaged in manufacturing electronic products increased faster than in those industries producing electrical items. Between 1958 and 1964, employment in three industry groups manufacturing electronics rose 37 percent, while employment in the five industry groups primarily engaged in manufacturing electrical products rose 12 percent.

During the 1958–64 period, nearly half of electronics shipments reportedly went into the Nation's military and space efforts. Many of the military-space products were complex, low volume items, which were not produced by mass production methods. On the other hand, many of the production processes in the electrical products industries involved the fabrication of metal or plastic parts, which were usually mass produced.

In 1964, about half of the workers in this major industry group were employed in three industry groups primarily engaged in manufacturing electronic products—communications equipment (which includes industrial, commercial, military and space products); electronic components; and radio and television sets and other home entertainment equipment. The remainder of the employees were apportioned among the five industry groups primarily engaged in manufacturing electrical equipment as follows: Electrical distribution equipment, 10 percent; electrical industrial apparatus, 12 percent; household appliances, 10 percent; electrical lighting and wiring equipment, 10 percent; and miscellaneous electrical equipment and supplies, 6 percent.

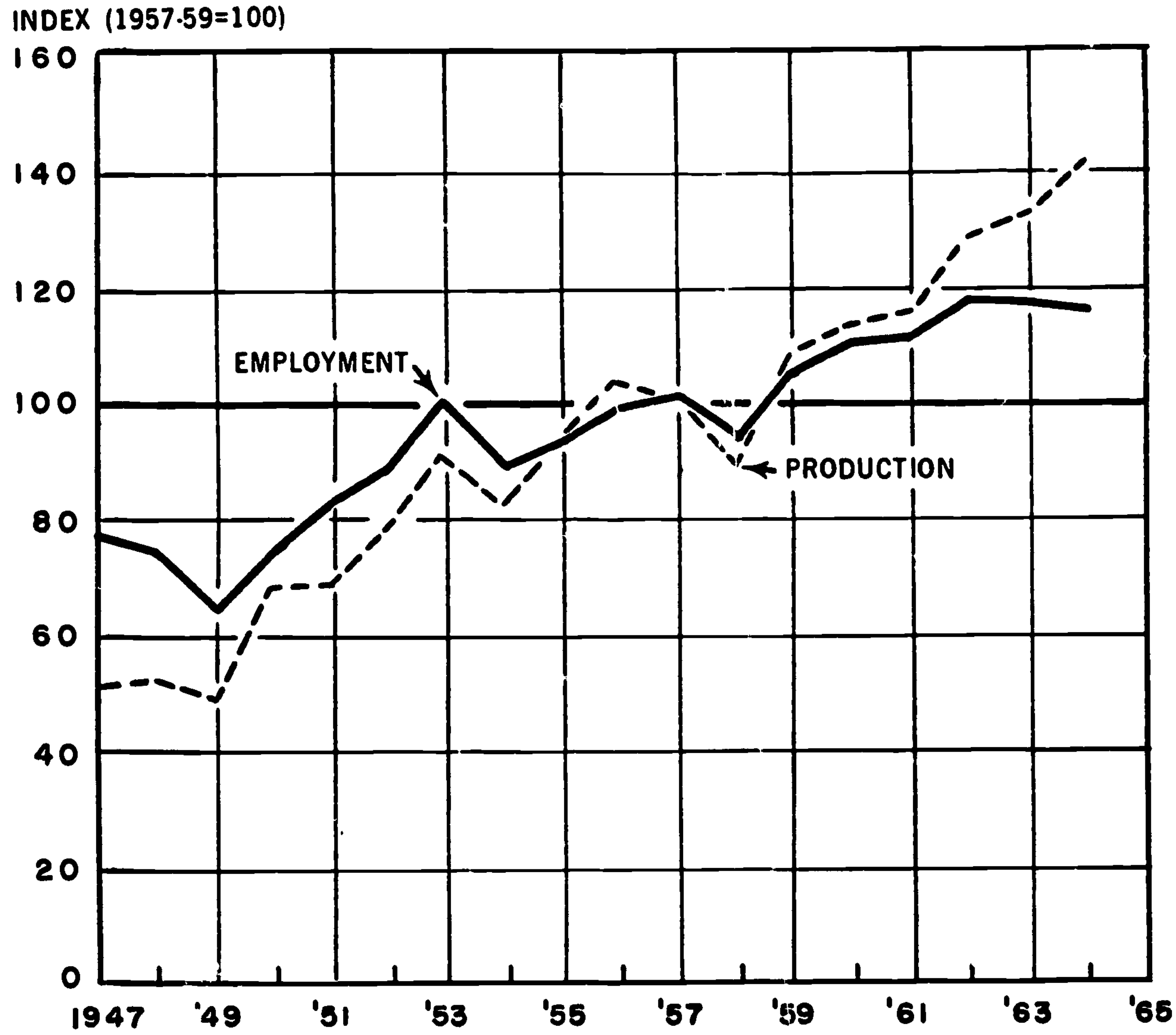
1964–75. Manpower requirements in the electrical machinery, equipment, and supplies major industry group are expected to increase rapidly through 1975, to about 2.0 million, or about 10 percent of all workers employed in manufacturing.

The projected increase in employment will result from the very rapidly rising demand for electronic and electrical products, particularly electronic products. While items for military and space efforts will continue to be needed, the demand for other products is expected to increase more rapidly than in the past because of rising levels of general economic activity, and increasing requirements for electrical and electronic products. For example, electrical equipment requirements in industrial plants are two to three times the amount needed 20 years ago; this trend is expected to continue and raise the demand for electrical products such as motors, wiring, lighting, and industrial controls.

The demand for electrical equipment should also be stimulated by improvements in urban transportation, including the construction of subway sys-

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN ELECTRICAL MACHINERY, EQUIPMENT, AND SUPPLIES, 1947-64

Employment (in 000's)	
1947	1,035
1948	991
1949	862
1950	991
1951	1,114
1952	1,185
1953	1,333
1954	1,190
1955	1,241
1956	1,323
1957	1,344
1958	1,249
1959	1,396
1960	1,467
1961	1,473
1962	1,568
1963	1,554
1964	1,548



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

tems that use electric power; by the construction of atomic powered electric utility systems; and by the installation of underground transmission systems. The mechanization and automation of many industrial processes will stimulate demand for electronic products such as instruments, controls, and closed circuit television.

It is anticipated that the growing commercial market for electronic data processing equipment and other electronic products will greatly increase the demand for electronic components. The rapid growth in population and family formation and the higher levels of personal spendable income are expected to provide booming markets for consumer and consumer-related items such as radios and television sets, electric light bulbs, and new home construction (which requires many electrical products). Electrical and electronic systems also will play a significant role in telecommunications, underwater research, medicine, electroluminescense, and optical technology.

Effects of Technological Developments on Future Employment

Technological developments are expected to continue affecting not only the level of employment, but worker skill requirements. Increasing mechanization and instrumentation of production processes will raise employment requirements for skilled maintenance workers and reduce employment requirements for machine operators.

One of the more significant technological innovations in this major industry group, affecting both production processes and product mix, has been the introduction of microminiature solid-state electronic components and circuitry such as integrated circuits, modular circuitry, thin films, and other microelectronics. First introduced into the sophisticated one-of-a-kind electronic systems for the military and space efforts, the use of solid-state circuitry is expected to become widespread throughout this major industry group.

Until recently, most electrical and electronic switching devices have been of an electromechanical nature. These switching devices are being replaced by electronic circuitry in products such as telephone switching apparatus, motor controls, ignition systems, and alternators. As a result, it is anticipated that more electronic technicians and inspectors will be needed in establishments producing this equipment. The manufacture of microelectronic circuitry is expected to become increasingly mechanized during the decade ahead, thus adversely affecting employment requirements for assemblers.

Increasing mechanization will tend to reduce unit labor requirements in the manufacture of products such as television and radio sets, components, and electric light bulbs, which are mass-produced. In these plants, electronic-controlled inspection and testing devices, and automatic insertion and transfer machines will reduce the requirements for assembling, inspecting, and testing workers. Electrostatic spray painting techniques in plants manufacturing household appliances will reduce the number of workers needed for these painting processes. Automatic conveyor systems will continue to eliminate significant numbers of materials handlers in many plants manufacturing electrical and electronic products. The greater use of computer-controlled and other new drafting techniques are expected to reduce engineering detail time and may adversely affect employment requirements for draftsmen.

Although the increasing use of electronic data processing systems will reduce the need for some kinds of clerical workers, it is expected that employment requirements for occupations such as operators of peripheral computer equipment and secretaries will increase. The demand for skilled maintenance personnel, particularly instrument repairmen, is also expected to rise, because of the need to maintain and repair the increasing amounts of complex machinery. The overall demand for engineers, scientists, and technicians is expected to increase because of the anticipated rising expenditures for research and development, and the continuing trend toward the production of complex equipment.

Transportation Equipment (SIC 37)

Summary

Employment in the transportation equipment major industry group is expected to increase slowly between 1964 and 1975, compared with a rapid rise between 1947 and 1964. Technological change is expected to play a significant role in restricting employment growth through the mid-1970's.

Employment Trends

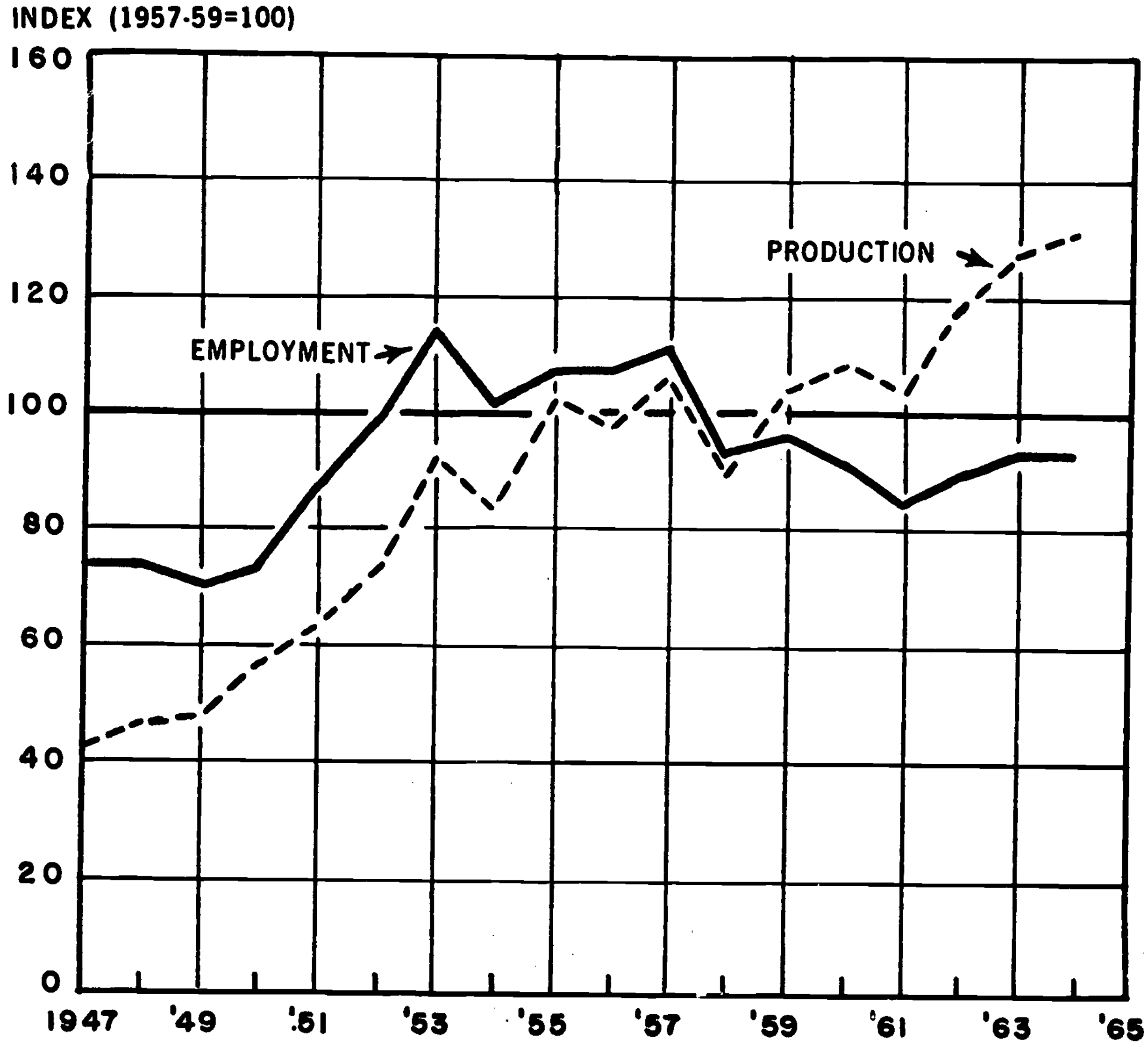
1947–64. Employment in this major industry group increased from 1.3 million to 1.6 million between 1947 and 1964—a gain of nearly 26 percent. Considerable variation in the level of employment occurred, however, during the intervening years. Employment increased rapidly between 1947 and 1953, primarily as a result of a large employment increase in the aircraft and parts industry group. In 1953, employment in the transportation equipment industry group numbered 2 million workers, the highest level it attained during the 1947–64 period. Employment remained at a relatively high level through the 1953–57 period, but drifted into a decline in 1958 that persisted through 1961 when employment bottomed-out at 1.5 million. This downturn was due, in part, to the overall decline in employment in the aircraft and motor vehicle industry groups. After 1961, employment turned upward primarily as a result of a substantial increase in motor vehicle manufacturing employment.

Nearly 85 percent of total employment in the transportation equipment major industry group is concentrated in the two largest industry groups—motor vehicles and motor vehicle equipment industry which accounted for almost half of transportation equipment employment in 1964; and aircraft and parts, which represented over one-third. The remaining workers are employed in the following industry groups: Ship and boat building and repair; railroad equipment; motorcycles, bicycles, and parts; and miscellaneous transportation equipment.

Though there was an overall increase in employment in the transportation equipment major industry group between 1947 and 1964, the rates of change among the individual industry groups differed substantially. Employment declined slightly in the large motor vehicle industry group as increased output per worker, in large part, offset increased production of motor vehicles. In contrast, employment increased rapidly in the aircraft and parts industry group because of: (1) An overall increase in Government procurement for aircraft and missiles for defense purposes, (2) the development and manufacture of space vehicles for an expanding space program, beginning in the late 1950's, (3) rising expenditures for research and development, which significantly increased the number of scientists, engineers, and techni-

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN TRANSPORTATION EQUIPMENT, 1947-64

	Employment (in 000's)
1947	1,275
1948	1,270
1949	1,210
1950	1,265
1951	1,515
1952	1,703
1953	1,969
1954	1,754
1955	1,855
1956	1,853
1957	1,909
1958	1,595
1959	1,635
1960	1,568
1961	1,449
1962	1,547
1963	1,610
1964	1,605



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

cians, and (4) increased demand for airplanes by the commercial airlines and other segments of civil aviation.

Employment in ship and boat building and repair declined overall between 1947 and 1964. Employment fell most rapidly in the years immediately following World War II as Government shipbuilding expenditures declined and many ships were relegated to the "mothball fleet". After substantial yearly declines in employment through 1950, sharp increases in defense expenditures, necessitated by the Korean emergency, resulted in a significant employment increase between 1950 and 1952. Since 1952, employment in the major industry group has remained at a relatively stable level, although far below that experienced during World War II.

Employment in the railroad equipment industry group declined significantly over the 1947–64 period. The conversion from steam to diesel locomotives that began in earnest at the end of World War II, was virtually completed by 1958. Once the conversion process was accomplished, most of the production activity in this industry group was devoted to the repair, modification, and replacement of existing diesel locomotives and freightcars, and the production of parts.

Employment increased moderately between 1958 and 1964 [22] in those establishments manufacturing other transportation equipment such as motorcycles, bicycles, and trailer coaches.

1964–75. Manpower requirements in transportation equipment manufacturing are expected to increase slowly in the years ahead. By 1975, employment needs in this industry may increase to slightly more than 1.7 million—a rise of approximately 7.8 percent from the 1964 level. The slight increase in employment requirements is expected primarily as a result of slow employment growth in the manufacture of motor vehicles and employment declines in establishments manufac-

[22] BLS employment (payroll) data for these industry groups are not available for the years prior to 1958.

turing aircraft and missile and spacecraft components. Increases in output per worker in motor vehicle manufacturing establishments are expected to limit employment growth, and increases in output per worker coupled with a declining market for military aircraft should cause employment to decline in establishments manufacturing aircraft and parts. Employment in the other industry groups (ship and boat building and repair; railroad equipment; and "other transportation equipment") may increase slightly. However, changes in Government policy relating to shipbuilding and shipping could affect the level of employment projected in shipbuilding.

Effects of Technological Developments on Future Employment

Technological change is expected to continue to increase output per worker in this major industry group. Laborsaving innovations will be significant in the aircraft and parts, and motor vehicles industry groups. (See individual statements that follow.) In comparison, the employment impact of technological development in the ship and boat building and repair; railroad equipment; and other transportation equipment industry groups is expected to be less significant.

Employment growth in machining occupations could be slowed by widespread use of numerical control during the 1964–75 period. Employment of machine tool operators is particularly vulnerable to this change and is likely to be reduced. Also, highly skilled craftsmen, such as toolmakers and setup men, are likely to be affected adversely since fewer jigs, fixtures, and machine setups will be required.

There is expected to be an increasing use of computers in office activities, operations research, production planning, inventory control, and in design, test, and evaluation. The use of electronic data processing systems (EDP) will reduce future requirements for routine clerical workers in activities such as billing, posting, filing, and maintaining records, and in some office machine jobs such as tabulating and bookkeeping. Central, integrated records systems may make inroads to further limit clerical employment. Computers also tend to reduce employment requirements in certain types of factory jobs because they allow tighter production standards and inventory control. Their use in production planning and in testing may also result in lower employment levels. Requirements for lower and middle management employees may also be affected by growing use of computers because of the centralization and coordination of decision-making and other organizational changes they make possible. On the other hand, opportunities may increase for occupations such as programer, console operator, and tape librarian.

In shipbuilding, a relatively recent development is "reduced scale lofting and optical marking." Reduced scale lofting consists of preparing very accurate drawings, one-tenth of full size, which are then photographed by a precision camera producing a negative to a scale of about one one-hundredth of full size. Two projectors are located above the layout tables and project this negative image vertically downwards, enlarged to full size onto the material to be laid out. Layout can be accomplished in the usual manner and cutting accomplished by portable burning equipment, or by hand torch. Alternatively, material can be burned automatically without layout by means of an electronic controlled automatic plate cutting process known as "Telerex." Reduced scale lofting and optical marking replaces the conventional full scale mold loft and layout making for increase accuracy of finished parts and a faster production flow. This new system may provide labor savings in those occupations involved in line development, patternmaking, and platemarking and shaping.

In shipyards, modified mass production methods performed on ground level also facilitate the movement of steel from storage yards through shop operations. Such ground fabrication, utilizing materials handling systems and machine welding equipment, are performed under relatively uncrowded conditions as opposed to accomplishing these same operations under the more crowded and difficult working conditions on the ship. To gain the benefits of these and other laborsaving developments requires considerable capital outlays by the shipbuilders. However, considering the limited ship construction likely in the future and the large number of companies competing for this business, industrywide adaptation of these developments may be limited.

The Government is looking into the feasibility of using computers in ship design and construction. If feasible, such techniques would reduce costs and "concept-to-delivery" time and, as a result, engineering and drafting employment.

Production techniques in the railroad equipment industry group do not lend themselves to highly automated methods. For example, limited assembly runs of any one of a large number of freightcar types, or of classes of locomotives, whose power capabilities and optional equipment range broadly, cannot economically be adapted to a highly automated assembly line operation. Some transportation equipment subassemblies are purchased from firms in other industries, and other components, such as diesel valves, are already being produced by automated machine methods. Thus, technological changes will have relatively little impact on employment in the railroad equipment industry group.

Motor Vehicle and Motor Vehicle Equipment (SIC 371)

Summary

Employment requirements in the motor vehicle and motor vehicle equipment industry group are expected to be only a little higher in 1975 than in 1964, despite a significant increase in production. Gains in output per worker are expected to increase nearly as fast as increases in production.

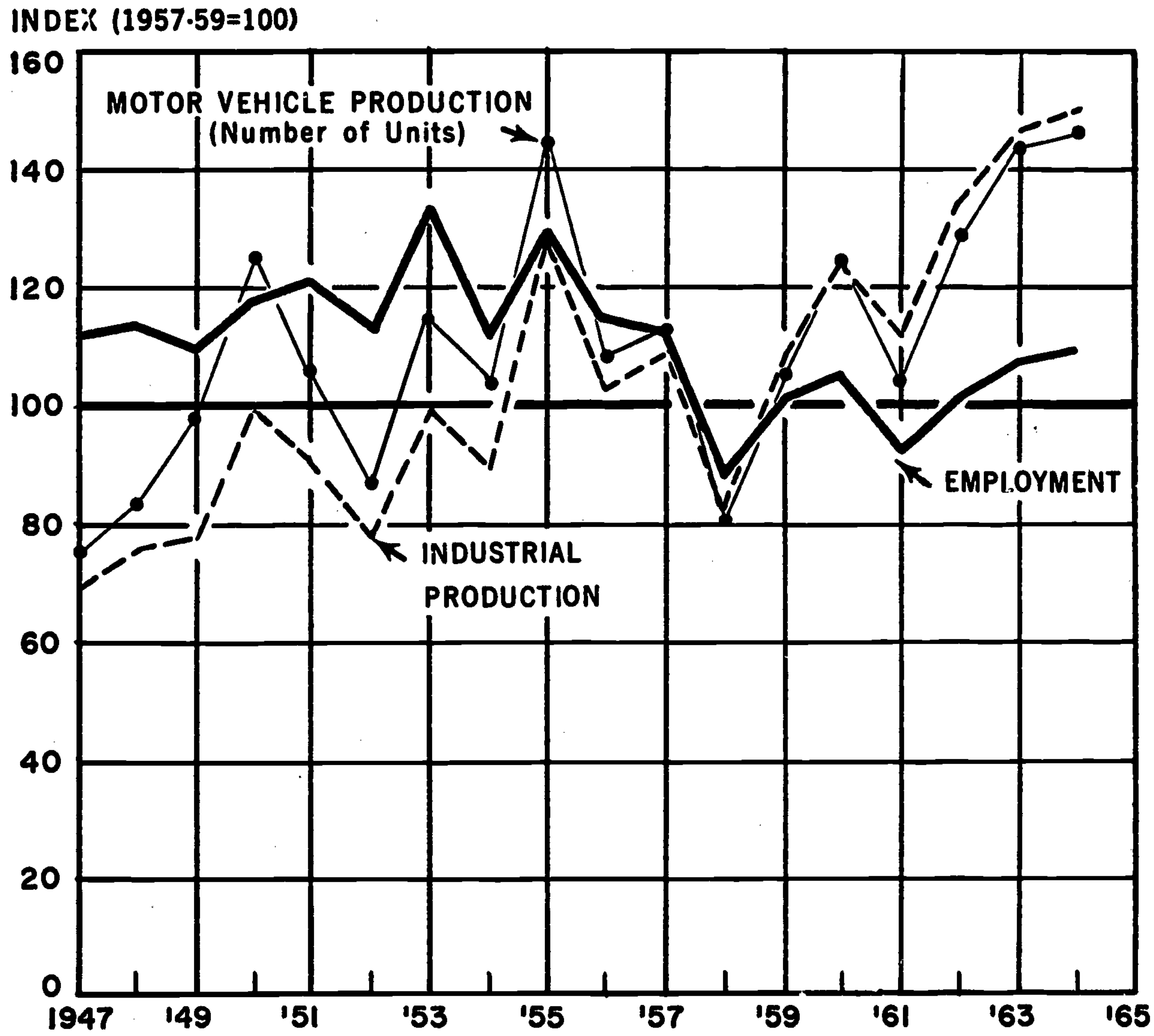
Employment Trends

1947–64. In the post-World War II period, employment in the motor vehicles and equipment industry group fluctuated between 600,000 and 900,000, reflecting the cyclical pattern of motor vehicle production and, to some extent, changes in defense expenditures. Although employment fluctuated sharply from year to year, the employment trend between 1953 and 1964 was downward. In contrast, the trend in motor vehicle production was upward.

Although motor vehicle production for civilian use was resumed in the latter part of 1945, it did not reach prewar levels until 1947. Employment rose from 768,000 in 1947 to an all-time high of 917,000 in 1953. This record employment level set in 1953 was a result of a very good production year for civilian motor vehicles (7.3 million) coupled with defense production resulting from

EMPLOYMENT AND PRODUCTION IN MOTOR VEHICLES AND MOTOR VEHICLE EQUIPMENT, 1947-64

Employment (in 000's)	
1947	768
1948	781
1949	751
1950	816
1951	833
1952	778
1953	917
1954	766
1955	891
1956	793
1957	769
1958	607
1959	692
1960	724
1961	632
1962	692
1963	741
1964	755



Source: Employment, Bureau of Labor Statistics; industrial production, Federal Reserve Board; motor vehicle production, Automobile Manufacturer's Association the Korean conflict. Employment dropped to about 766,000 in 1954, as a cutback in defense spending, and a general contraction of economic activity caused a drop in production. In the following year, employment rebounded to 891,000 as a combination of favorable forces—good business conditions, easy credit, and major styling changes—spurred production to an unprecedented high of 9.2 million vehicles.

Employment declined steadily after 1955, to a postwar low of 607,000 in 1958, a recession year in which only 5.2 million motor vehicles were produced. After increasing steadily from 1961, production reached an all-time high of 9.3 million motor vehicles in 1964. In the same year, employment reached 755,000—the highest level since 1957, but a level that was exceeded in 9 of the 10 years between 1947 and 1956. (During 1965, employment continued to increase as production set new highs; as a result, motor vehicle employment in 1965 will probably be about 850,000, the third highest in the industry's history.)

Between 1947 and 1964, production workers as a proportion of total employment in this industry group declined from 82 to 77 percent; however, this proportion has remained relatively stable since 1959.

1964–75. Employment requirements in motor vehicle and equipment manufacturing are expected to be about 800,000 in 1975, approximately 6 percent above the 1964 level (but below the 1965 level), as substantial increases in the production of motor vehicles and equipment are partially offset by increases in output per worker. Output will be spurred by increases in population, households, multicar ownership, personal spendable income, and a continuing shift of population to the suburbs.

Effects of Technological Developments on Future Employment

Technological developments are expected to have a significant effect on the characteristics and number of jobs in motor vehicles and equipment manufacturing through the mid-1970's. Employment requirements are expected to be influenced substantially by the greater use of computers and numerically controlled machine tools, automation and mechanization of existing manufacturing processes, design innovations, and new materials and manufacturing processes.

The more widespread use of computers for accounting and administrative purposes is expected to limit increases in the employment of accountants, auditors, and clerical occupations such as bookkeepers, and shipping and receiving clerks. Need for inspectors will probably be adversely affected by the increasing use of computers in quality control. Computers also are expected to be used increasingly to solve design-engineering problems, and thereby slow the growth in employment of engineers. The industry hopes to use computers in conjunction with cameras and other equipment to convert designer's models into data that would be fed into numerically controlled die mills to produce the dies for new automobiles. Such a procedure could reduce the need for designers, draftsmen, model makers, and tool and die makers. Although the growing use of computers will adversely affect employment in some occupations, it is expected to increase the need for programers and punchcard operators.

Motor vehicle and equipment manufacturers are expected to use increasing numbers of numerically controlled machine tools, especially for tool and die making. The greater use of these machines should tend to reduce the need for toolmakers, setup men, and machine tool operators, since items produced generally are of more uniform quality than those produced by conventional methods.

Motor vehicle and equipment manufacturers are continuously finding ways to improve production efficiency by redesigning parts and adopting new materials and manufacturing processes. Improvements in casting, stamping, and forging processes are expected to reduce the amount of machining needed to finish parts, thus reducing the need for machine tool operators. The more widespread use of the "reflow" paint system, which produces a finish needing little polishing, should tend to reduce employment of polishers. New materials, such as molded carpets and electrically embossed interior trim, are expected to reduce the need for cutters, sewing machine operators, and trimmers. An increase in the installation of windshields by means of an adhesive sealant, which eliminates the need for rubber moldings, will adversely affect the need for glaziers.

Some intermediate fabrication and assembly operations have been automated and many more such operations are expected to be automated in the future. Recent developments include: An automated system that gives fenders, hoods, and quarter panels a prepaint treatment, thus adversely affecting the need for sprayers; automated equipment that machines pistons and other engine parts, thus reducing the need for machine tool operators; and automated systems that assemble brake drums, differentials, and alternator rectifiers, thus reducing the need for assemblers. Although additional automation will reduce the need for processing, fabricating, and assembly workers, it will increase requirements for maintenance workers.

Aircraft and Parts (SIC 372)

Summary

Employment requirements in the aircraft and parts industry group are expected to decline only slightly between 1964 and 1975, compared with a very rapid increase between 1947 and 1957, and a rapid decline between 1957 and 1964. It is assumed that changes in the level and mix of defense expenditures will not result in a significant increase in aircraft production. Technological innovations are expected to be a major factor contributing to the employment decline in this industry group in the decade ahead.

Employment Trends

1947–64. Employment in the aircraft and parts industry group more than tripled between 1947 and 1957, growing from 239,000 to 896,000. Since 1957, employment has declined by almost one-third, dropping to about 604,000 in 1964.

More than 80 percent of total employment in the aircraft and parts industry group is concentrated in the two largest industries—aircraft, which employed about half of the industry group's workers in 1964, and aircraft engines and engine parts, which accounted for almost a third. Other industries in this industry group are aircraft propellers and propeller parts, and other aircraft parts and auxiliary equipment. Employment in two major industries, aircraft and aircraft engines and engine parts closely followed the trend of total employment.

The downward trend in employment beginning in 1958 resulted primarily from the decline in production of military aircraft for the Federal Government, which has purchased about four-fifths of the industry's output in recent years. Since 1958, the Government's greater emphasis on the development and production of missiles and space vehicles has resulted in some increase in the demand for components produced by the industry, but in terms of employment, this has been more than offset by the decline in demand for military aircraft.

The growing emphasis on research and development between 1955 and 1964 was largely responsible for a rise in the proportion of nonproduction workers from 31 percent to 44 percent. Increasing numbers of scientists, engineers, technicians, and supporting managerial and clerical personnel were required to develop spacecraft, missiles, and more complex aircraft particularly in the vertical-lift and supersonic categories.

1964–75. Manpower requirements in this industry group are expected to decline about 5 percent between 1964 and 1975, to about 575,000. These projections are based on the expectation of continuing large expenditures on space research and development. They also assume no significant change in the level of defense expenditures or present trends in the overall mix of military goods.

The projected employment decline is expected to result from greater use of laborsaving technological developments such as numerically controlled machine tools. In addition, it is expected that military and commercial demand for aircraft products will remain relatively stable over the 1964–75 period. Little or no change is anticipated in employment of those engaged in aircraft development and production, although efforts to develop the supersonic transport and the C–5A cargo transport may lead to an increase in the number of engineers, scientists, and technicians engaged in this activity. Employment of workers engaged in missile work in aircraft plants is expected to decline as emphasis shifts from missile production to advance missile development. On the other hand, workers engaged in research and development in space science and in the production of spacecraft and related equipment may increase moderately because of the continuing effort to accomplish a lunar landing and exploration by the early 1970's.

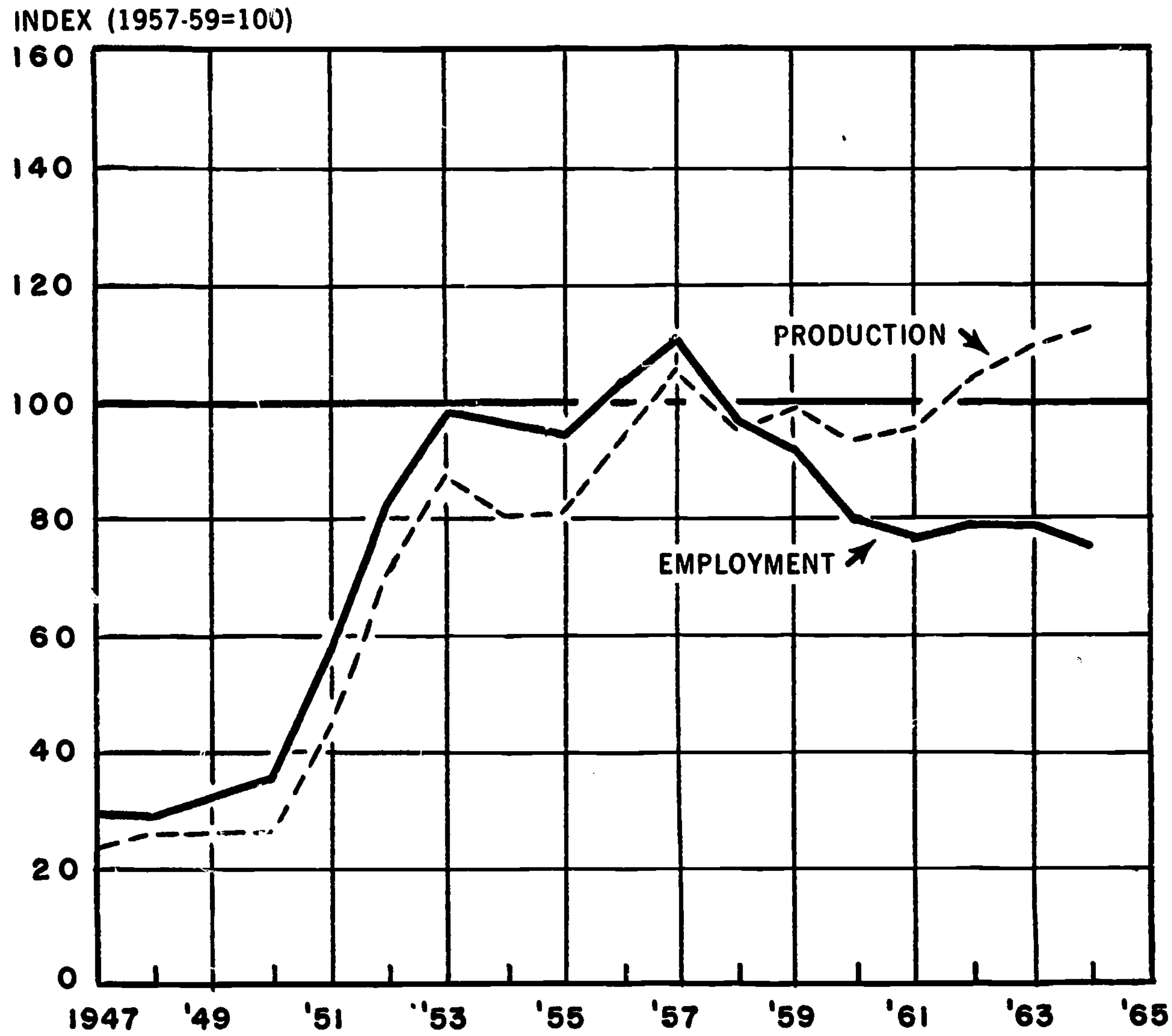
Effects of Technological Developments on Future Employment

Technological change is expected to continue to be very fast in the aircraft industry through the mid-1970's.

The nature of the products expected to be produced in this industry group indicate that metalworking, metal fabrication, and the assembly of electronic equipment will continue to be major activities in the aircraft and parts industry. The most significant metalworking development in this industry for the future appears to be numerical controlled machining (N/C). Laborsaving tape-controlled tools are particularly important in short production runs of intricate shapes common in prototype development of aircraft and space vehicles. In 1962, aerospace firms were using more than 400 numerically controlled tools. About 1,600 are expected to be in use by 1970. Additional operations, such as drafting, welding, and inspection are being adapted to numerical control. Estimates of the reduction in unit labor requirements possible in machining operations through use of this technique reportedly range from 20 to 80 percent. Employment of machine tool operators is particularly vulnerable to the use of N/C machines and will likely be reduced. Highly

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN AIRCRAFT AND PARTS, 1947-64

Employment (in 000's)	
1947	239
1948	238
1949	264
1950	283
1951	468
1952	671
1953	796
1954	783
1955	761
1956	837
1957	896
1958	771
1959	721
1960	628
1961	610
1962	638
1963	639
1964	604



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

skilled craftsmen, such as toolmakers and setup men, are also likely to be affected adversely since fewer jigs, fixtures, and machine setups will be required.

High temperatures, pressures, and stresses of space exploration require increasing use of new materials that cannot be cut, shaped or joined by conventional processes. To overcome such problems, efforts are being made to develop new methods of processing. Processing techniques now under development or already in limited use include new metal forming methods, such as high energy rate forming; brazing with new compounds; new adhesive bonding methods; welding and cutting with electron beams; and nonmechanical metal removal methods, such as chemical milling and electrochemical machining. These changing techniques involve development of new skills and place increased emphasis on worker retraining.

Of increasing importance in the aircraft industry is the assembly and installation of miniaturized equipment used in aircraft, missiles, and spacecraft, especially complex electronic component parts. Some industry officials feel that miniaturization of electronics hardware (for example, transistors, printed circuit boards, thin-film circuits) will become increasingly important during the 1964–75 period and will tend to increase the skill level of those doing electronics assembling.

The continuing emphasis by the Department of Defense and its contractors on cost reduction is likely to stimulate the rate of introduction of laborsaving innovations in the aircraft and parts industry group in the years ahead.

Professional, Laboratory, and Scientific and Research Instruments; Photographic and Optical Goods; and Watches and Clocks (SIC 38)

Summary

Employment requirements in the instruments and allied products major industry group are expected to increase rapidly between 1964 and 1975. The growing application of laborsaving technological innovations is expected partially to offset the anticipated rapid increase in production, thus limiting the growth in labor requirements.

Employment Trends

1947–64. Employment in the instruments and related products major industry group increased more than three times as rapidly as total manufacturing employment in the post-World War II period. In 1947, 267,000 workers were employed in this major industry group; by 1964, employment had risen to 369,000.

In 1964, almost one-half of these workers were in the industry groups that manufactured scientific and related instruments, including engineering, laboratory, and scientific and research instruments; measuring, controlling, and indicating instruments; and optical instruments and lenses.[23] About 20 percent were employed in establishments making photographic equipment and supplies. The remaining workers were in establishments producing surgical, medical, and dental instruments; ophthalmic goods; and watches and clocks.

Between 1958 and 1964,[24] employment growth among the industry groups differed widely, reflecting differences in the increases in product demand and in the rate of introduction of laborsaving innovations. Employment increased fastest (almost 40 percent) in establishments manufacturing optical instruments and lenses as many industries—including aerospace, automotive, chemical, and food manufacturing—increased their use of optical instruments to improve both their manufacturing process and quality control.

Employment in establishments manufacturing photographic equipment; surgical, medical, and dental instruments; ophthalmic goods; and watches and clocks also rose rapidly between 1958 and 1964, despite the increased application of laborsaving equipment. Employment in establishments producing photographic equipment rose 13 percent, reflecting the growth of the population, rising levels of disposable personal income, increased leisure time, and expanding exports. The number of workers in establishments manufacturing surgical, medical, and dental instruments increased by almost 25 percent. These employment gains can be traced primarily to greater demand for medical and dental care due to an expanding population, changes in the age composition of the public (more older people), increased health consciousness, and the extension of prepayment plans for medical care and hospitalization. Employment rose by about 12 percent in establishments manufacturing ophthalmic goods, reflecting increases in the size, literacy, and educational level of the population; the rising number of older persons; and increasing emphasis on good vision. The number of workers in establishments producing watches and clocks rose almost 15 percent, primarily reflecting increases in population and family income.

The number of workers in establishments manufacturing engineering, laboratory, and scientific and research instruments rose nearly 8 percent, and employment in establishments producing measuring, controlling, and indicating instruments increased by about 11 percent, reflecting a rapid growth in their use in industry generally. Because of the diversity of their products, these industries are affected by overall economic trends. However, demand for these products is especially sensitive to spending for capital investment and research and development in direct user industries. Capital investment and expenditures for research and development rose rapidly during the 1958–64 period.

1964–75. Employment requirements in the instruments and allied products major industry group are expected to increase rapidly in the years ahead, despite the increasing use of laborsaving technological innovations. By 1975, employment requirements could reach 510,000, almost two-fifths above the 369,000 employed in 1964. Output is expected to be stimulated by the rapid increase in demand for instruments and allied products by manufacturing and utility industries.

Employment trends for the individual industries within the major group are expected to differ only slightly due to differences in demand. The use of technological innovations is not expected to have a significant impact on employment growth. Worker requirements are expected to increase rapidly in those industry groups that manufacture scientific and related instruments, because of increased capital spending for modernization of industrial production processes and increased expenditures for research and development. Research and development activity is expected to lead to the development of many new instruments and the

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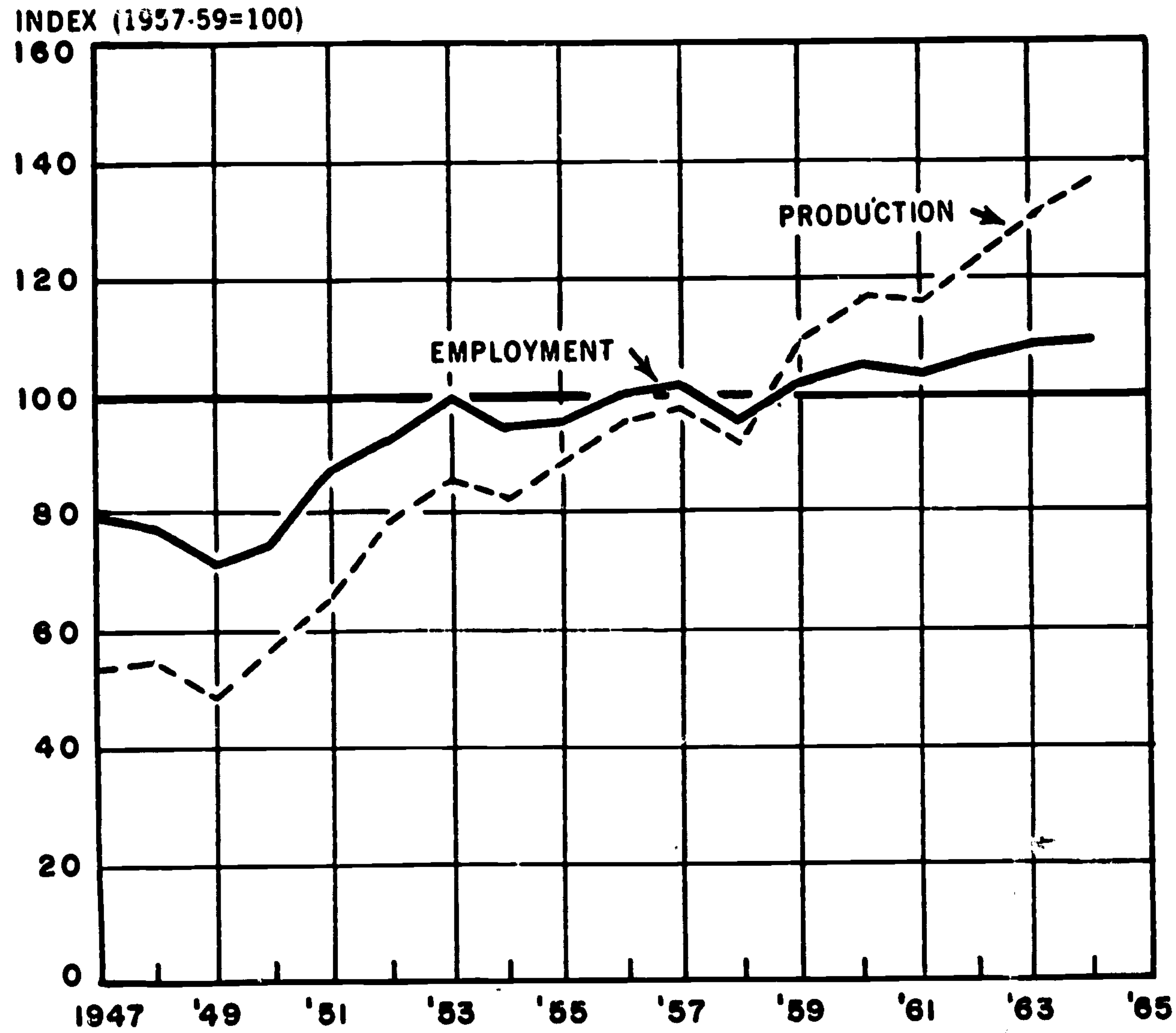
[23] Electrical instruments are classified in the electrical machinery major industry group (SIC 36).

[24] BLS employment (payroll) data are not available for all industry groups for the years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN PROFESSIONAL, LABORATORY, AND SCIENTIFIC AND RESEARCH INSTRUMENTS; PHOTOGRAPHIC AND OPTICAL GOODS; AND WATCHES AND CLOCKS, 1947-64

Employment (in 000's)	
1947	267
1948	262
1949	239
1950	250
1951	294
1952	313
1953	337
1954	321
1955	323
1956	338
1957	342
1958	324
1959	345
1960	354
1961	347
1962	359
1963	365
1964	369



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

refinement of those now in use. Expanding activity in fields such as air purification, including environmental control, vehicle exhaust control, and better methods of weather forecasting also will expand the demand for scientific instruments and related products.

Employment growth in the surgical, medical, and dental instruments and supplies sector, as well as in the ophthalmic goods sector, will stem from rising demand for health services by an expanding population and by an increasing number of persons 55 years old and over, augmented by extension of prepayment plans for medical care and hospitalization and rising levels of personal disposable income. An expanding population and rising levels of disposable income are also expected to be significant factors in increasing the demand for watches, clocks, and photographic equipment.

Effects of Technological Developments on Future Employment

Increasing use of laborsaving technological innovations in this major industry group is expected to reduce unit labor requirements through the mid-1970's. Increasing use of numerically controlled machine tools, particularly in the production of scientific and engineering instruments, is expected to reduce substantially unit labor requirements, lower scrap and inventories, shorten lead time in production, and permit manufacture of intricate parts previously considered uneconomical. The greater use of these tools will reduce manpower requirements for machine tool operators. On the other hand, the use of this equipment is expected to increase employment requirements for engineers, technicians, and workers skilled in the operation of electronic data processing equipment.

Conveyor lines will be used increasingly to speed the assembly of precision instruments and reduce inventory requirements. Moving from one bench to another via conveyor lines, instruments pass through all assembly stages including testing and packaging. Increased use of conveyor lines could reduce unit labor requirements for assemblers and materials handling personnel.

In establishments producing large quantities of standardized products, the use of automatic transfer equipment will become more important. Transfer machines are multistation machines that automatically load and unload the work piece at each station and move it from station to station. Separate operations are performed at each station. The greater use of automatic transfer equipment is expected to reduce unit labor requirements for machine tool operators and materials handling laborers.

Industrial engineering techniques are expected to be used increasingly to improve production efficiency, such as shorten lead time. These techniques include Monte Carlo simulation, operations research, and critical path and PERT (performance evaluation and review technique) analyses. Electronic data processing systems are being introduced as an aid in inventory and cost control. These systems enable management to keep a constant check on quality and obtain the maximum utilization of men, machines, and inventories.

In the manufacture of pin-lever watches, improvements are being made in product design and assembly to reduce the need for hand adjustments, which may reduce employment requirements for assemblers and inspectors and increase requirements for machinists and repairmen.

Improvements in automatic manufacturing facilities for cameras have paralleled the development and introduction of new products and models. Improvements include the introduction or improvement of conveyor belts, automatic transfer equipment, electronic testing equipment, and production control devices. Functions that can already be performed automatically include: Checking shutters, riveting shutter covers, fabricating and assembling plastic windows, assembling front and rear halves of cameras, and fastening camera halves. Probing, sensing, and ejecting stations will be incorporated increasingly. The continued introduction of this improved equipment could reduce employment requirements for assemblers, testers, and inspectors. Conversely, employment requirements for maintenance and repairmen, particularly instrument repairmen, is expected to increase with the increased application of more automatic equipment.

Miscellaneous Manufacturing Industries (SIC 39)

Summary

Employment requirements in the diverse group of industries which make up the miscellaneous manufacturing industries major industry group are expected to increase by almost one-fifth between 1964 and 1975, somewhat faster than the rate of employment growth between 1958 and 1964. Technological change is expected to have little effect on employment growth in these industries through the mid-1970's.

Employment Trends

1947–64. Employment in the miscellaneous manufacturing industries major industry group declined by more than 12 percent between 1947 and 1958, falling from 421,000 to 373,000. In 1958, however, this downward trend was reversed, and between 1958 and 1964, employment rose by 7 percent, to 399,000. Over the 1947–64 period as a whole, the decline in employment amounted to slightly more than 5 percent.

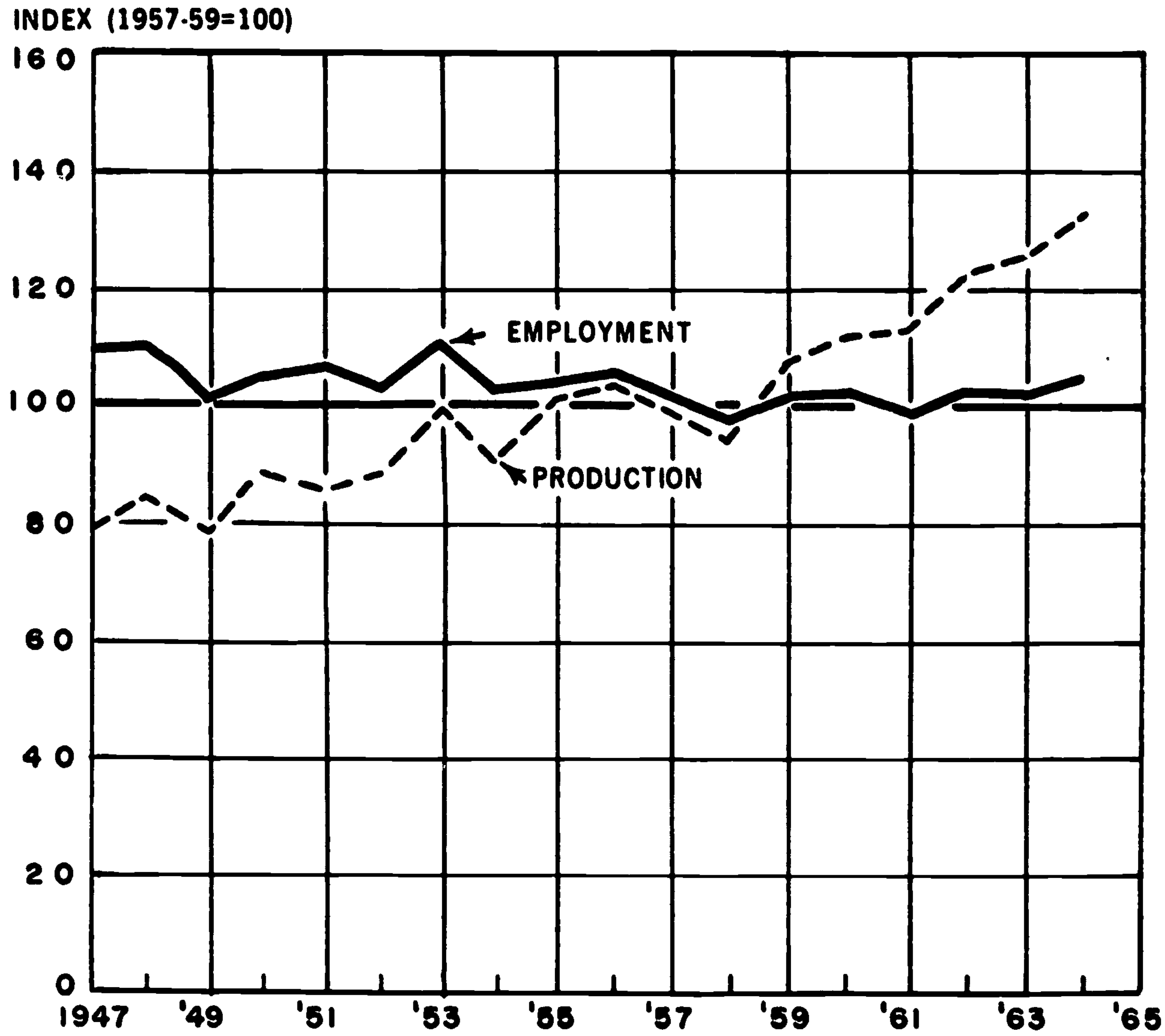
In 1964, about three-fifths of total employment in miscellaneous manufacturing was concentrated in four industry groups: Toys, amusements, sporting and athletic goods (27 percent); costume jewelry, costume novelties, buttons, and miscellaneous notions, except precious metals (14 percent); jewelry, silverware, and plated ware (11 percent); and pens, pencils, and other office and artists' materials (8 percent). The remaining workers were employed in plants manufacturing musical instruments and miscellaneous manufactured products including brooms, linoleum, matches, candles, lamp shades, morticians' goods, furs, signs and advertising displays, and umbrellas.

Between 1958 and 1964,[25] employment increased in all component industries of this major industry group, except costume jewelry. The most rapid employment increase occurred in establishments producing toys, and amusements and sporting goods. Demand for these products, as well as items produced by other miscellaneous manufacturing industries, was stimulated by increasing population, particularly in the number of young

[25] BLS employment (payroll) data are not available for all industry groups for the years prior to 1958.

EMPLOYMENT AND INDUSTRIAL PRODUCTION IN MISCELLANEOUS MANUFACTURING, 1947-64

Employment (in 000's)	
1947	421
1948	422
1949	385
1950	400
1951	406
1952	394
1953	421
1954	391
1955	396
1956	403
1957	387
1958	373
1959	388
1960	390
1961	378
1962	390
1963	387
1964	399



Sources: Employment, Bureau of Labor Statistics; production, Federal Reserve Board

people; rising personal disposable income; and more leisure time.

1964–75. Employment requirements in this major industry group are expected to increase from 399,000 in 1964 to approximately 475,000 in 1975, a rise of about 19 percent. Production is expected to increase rapidly, stimulated by the same factors as in the past. In addition, the number of new family formations is expected to rise significantly beginning in the late-1960's, which should spur demand for such items as household accessories and toys.

Within the miscellaneous manufacturing industries major industry group, increases in labor requirements are expected to take place in the manufacture of toys and amusement, sporting and athletic goods, as well as in the manufacture of musical instruments, and miscellaneous manufactured products. Requirements in both the jewelry and silverware and the costume jewelry industries are expected to decline.

Effects of Technological Developments on Future Employment

Limited information on technological developments in this mixed group of industries indicates that technological innovations have penetrated this industry only slightly, and this trend is not expected to be reversed in the near future. In general, the establishments in this industry are relatively small in size and some of the products, like precious and costume jewelry, are largely handmade and produced in relatively limited quantities. In the manufacture of precious jewelry, for example, little technological change has occurred and hand craftsmanship is still essential to jewelry manufacturing. Although the manufacture of costume jewelry is becoming more mechanized, hand assembly and finishing operations will continue to be necessary. However, in some production operations improvements in industrial machinery that increase output per worker are being made and are expected to continue in the future. For example, in the casting process continued improvements in the operating speed, capacity, and instrumentation of equipment have occurred, resulting in faster production of better quality castings with reduced unit labor requirements.

Transportation and Public Utilities (SIC Division E)

Summary

Employment requirements in the transportation and public utilities industry division are expected to increase moderately between 1964 and 1975 to service an expanding and more affluent population. Technological change is expected to be a significant factor in limiting employment growth in this division through the mid-1970's.

Employment Trends

1947–64. Employment in the transportation and public utilities industry division declined slightly in the post-World War II period. In 1947, 4.2 million workers were employed in this industry division; by 1964, employment had decreased by about 5 percent to 3.9 million workers. In this period, average annual employment dropped below 4 million workers for the first time in 1958 and remained at a postwar low of 3.9 million from 1961 through 1964.

In 1964, about 45 percent of total transportation and public utility employment was concentrated in two major industry groups—motor freight, which accounted for nearly a fourth of employment, and communications, which represented a fifth. The railroads employed about 19 percent of the division's workers (compared with 37 percent in 1947). The fourth major industry group, electric, gas, and sanitary services, accounted for 16 percent of employment in the division. Other major industry groups in the division include local and interurban passenger transit; transportation by air, by water, and by pipeline; and transportation services, such as freight forwarding and stockyards.

The employment trends between 1947 and 1964 varied widely among the major industry groups. Rapid employment growth occurred only in motor freight and air transportation. Between 1947 and 1964, motor freight employment grew by about two-thirds; over the 1958–64 period, employment in this industry increased by 18 percent. Over this latter period,[26] employment in air transportation increased nearly 30 percent. The only other major industry groups to experience overall employment growth were water transportation and transportation services, combined;[27] and electric, gas, and sanitary services. Employment in electric, gas, and sanitary services increased rapidly up to the late 1950's, but leveled off between 1957 and 1964.

Employment in the remaining industry segments declined over the years for which employment data are available. The most rapid employment declines occurred in railroad and pipeline transportation. Railroad employment in 1964 was less than half that recorded for 1947. Between 1958 and 1964, both railroad and pipeline employment dropped by over 20 percent.

1964–75. Manpower requirements in the transportation and public utilities industry division are expected to increase moderately through the mid-1970's. The number of workers employed in this industry division may reach 4.4 million by 1975, 12 percent higher than the nearly 4 million workers employed in 1964. Manpower requirements in the transportation industries are expected to increase slightly faster than the division as a whole.

Little or no change, however, is expected in the employment requirements of the communications and public utility groups. Manpower requirements in the communications industry group will increase slowly, if at all, despite the high level of activity projected for the telephone and broadcasting segments of the communications industry. Although little or no change is anticipated in the manpower requirements of electric, gas, and sanitary services, output in all segments of this industry group is expected to continue to increase rapidly as a result of population and business expansion. These rapid increases in output, however, are expected to be approximately offset by gains in output per worker.

Effects of Technological Developments on Future Employment

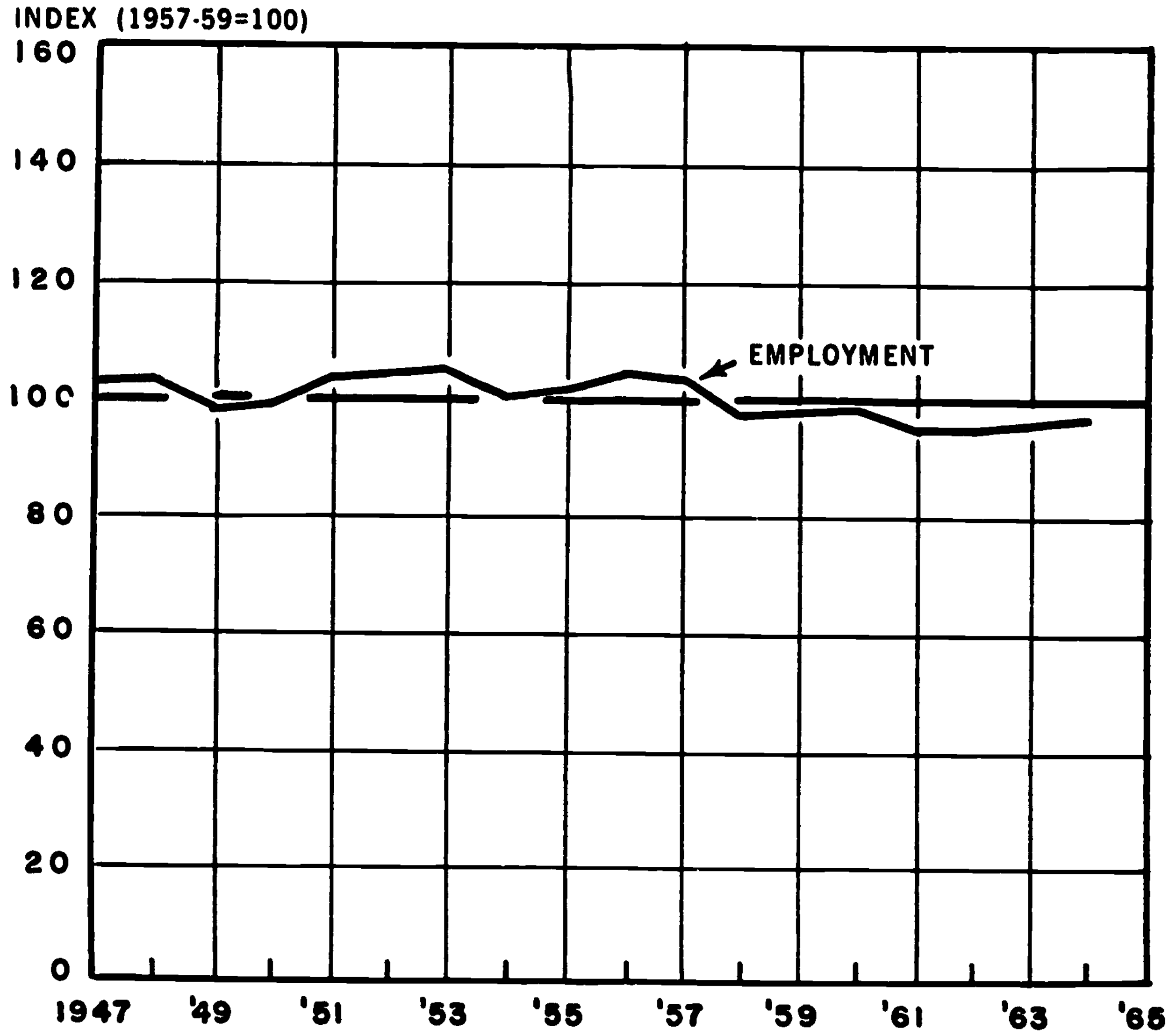
In terms of employment, continued improvements in the technology of the transportation, communications, and public utility industries are expected to offset most of the anticipated expansion in output in the years ahead. The most significant technological developments affecting these indus-

[26] BLS employment (payroll) data are not available for 6 of the 9 major industry groups in this industry division for the years prior to 1958.

[27] BLS employment (payroll) data for the water transportation and transportation services major industry groups are reported in a single series.

EMPLOYMENT IN TRANSPORTATION AND PUBLIC UTILITIES, 1947-64

Employment (in 000's)	
1947	4,166
1948	4,189
1949	4,001
1950	4,034
1951	4,226
1952	4,248
1953	4,290
1954	4,084
1955	4,141
1956	4,244
1957	4,241
1958	3,976
1959	4,011
1960	4,004
1961	3,903
1962	3,906
1963	3,903
1964	3,947



Source: Bureau of Labor Statistics

tries will involve higher capacity equipment, such as larger truck-tractors and higher-capacity electric generating equipment, which will result in an expansion of output without corresponding increases in employment. The expanded application of electronic data processing equipment to all sectors of transportation, communications, and public utilities will improve office operations and limit growth in the need for clerical employees. In addition, data processing equipment coupled with improved communications facilities will play an increasingly important role in advanced planning and adminstrative decisionmaking. (See individual statements that follow.)

Railroad Transportation (SIC 40)

Summary

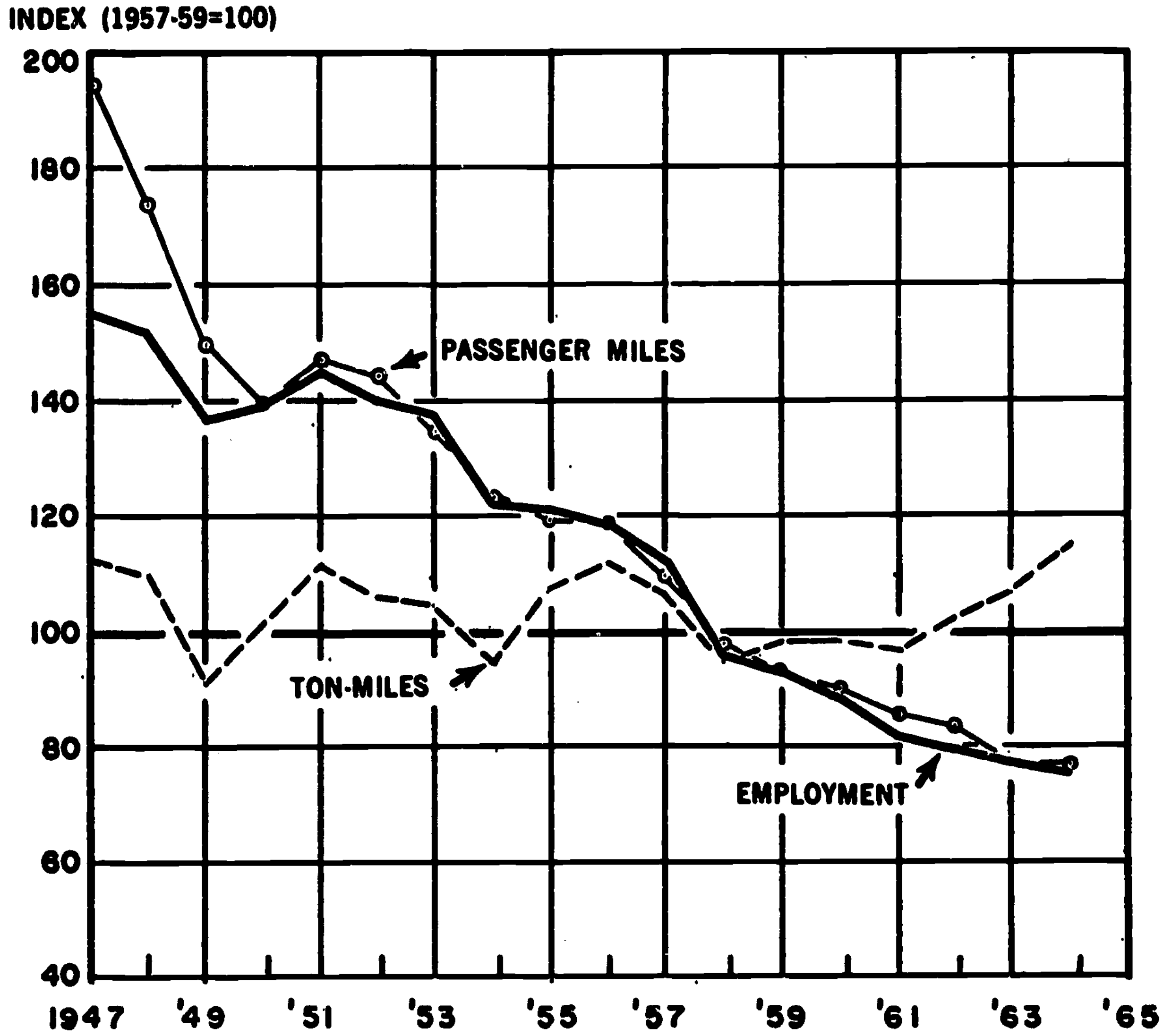
Employment requirements in the railroad transportation industry group are expected to continue to decline during the remainder of the 1960's and then begin to increase sometime in the early 1970's. Between 1947 and 1964, employment fell by more than 50 percent. A continued decline in passenger traffic and decreases in unit labor requirements resulting from technological innovations are expected to partially offset the increase in freight traffic.

Employment Trends

1947–64. Employment in this major industry group decreased from about 1.6 million in 1947 to 756,000 in 1964, a decline of more than 50 percent. In 1964, nearly 88 percent of all workers in this major industry group were employed by Class I

EMPLOYMENT AND INTERCITY TON-MILES AND PASSENGER MILES IN RAILROAD TRANSPORTATION, 1947-64

Employment (in 000's)	
1947	1,557
1948	1,517
1949	1,367
1950	1,391
1951	1,449
1952	1,400
1953	1,377
1954	1,215
1955	1,205
1956	1,190
1957	1,121
1958	957
1959	925
1960	885
1961	817
1962	796
1963	772
1964	756



Source: Employment, Bureau of Labor Statistics; intercity ton-miles and passenger miles, Interstate Commerce Commission

line-haul railroads. The remaining workers are distributed between Class II railroads and services allied to rail transportation, such as sleeping and dining car services, railway express, and switching and terminal companies. Over the 1947–64 period, employment in Class I line-haul railroads declined slightly slower (51 percent) than the remaining industry sectors combined (55 percent).

The rapid decline in railroad employment in the post-World War II period resulted mainly from a rapid decline in passenger traffic and advancements in technology. Railroad passenger miles dropped steadily from 46.8 billion in 1947 to 18.4 billion in 1964, a decline of over 60 percent. Although revenue ton-miles by rail carriers were slightly higher in 1964 (673 billion) than in 1947 (665 billion), freight traffic activity was not a major influence on the longrun decline in railroad employment.

One of the major technological developments that affected employment requirements was the transition in motive power from steam to diesel-electric. The diesel locomotive not only hauls larger and heavier trains than its predecessor, but also has reduced maintenance requirements. Railroad employment in the post-World War II period also was affected by the expanding use of mechanical equipment to maintain the roadway, the application of automatic control to freight classification activities, and a reduction in the miles of track through the use of centralized traffic control and elimination of some branch lines. In addition, the increasing application of electronic data processing systems to accounting and recordkeeping activities contributed to the reduction in employment needs in the industry.

1964–75. Employment requirements in this major industry group are expected to continue to decline through the remainder of the 1960's. By the early 1970's, however, the employment trend is expected to reverse and requirements should reach

820,000 by 1975, in response to growth in freight activity. This upward trend in freight traffic, which is expected to more than offset the effects of a continued decline in passengers, will result from transportation demand generated by the high levels of economic activity anticipated in the next decade.

Technological innovations are expected to limit growth in employment requirements in this major industry group. However, the cost reducing effect of improved technology is expected to enable railroads to capture a larger share of the Nation's freight traffic.

A continuation of the present trend in railway mergers, particularly of roads with parallel lines, could substantially reduce employment opportunities for railroad workers. Such mergers permit the elimination of roadway, trackage, and signal facilities, as well as the consolidation of terminals. However, with an improving freight traffic situation, railroad management may be hesitant to reduce facilities until new traffic patterns are determined.

Effects of Technological Developments on Future Employment

Changing technology is expected to continue to have a significant effect on the number and characteristics of jobs in this major industry group through the mid-1970's. For example, second generation diesel-electric locomotives with horsepower ratings in excess of 2,500 should displace the original 1,200- to 2,000-horsepower diesel-electrics. Because these more powerful locomotives will be able to pull heavier loads at greater speeds than the engines they displace, relatively fewer of them will be needed and labor requirements for maintenance employees may also be reduced.

Higher capacity rolling stock, made possible through design improvements and the use of lightweight construction materials such as aluminum and lightweight steel is expected to be used increasingly. Larger boxcars, some especially designed to handle unitized freight, are already replacing conventional units. Tank and flatcars are being designed and produced with double or more the capacity of earlier models. Greater specialization in rolling stock is also taking place. Special purpose cars capable of carrying large quantities of liquid or dry bulk commodities will be available, as will cars with special features for loading and hauling large or heavy items such as automobiles. One of the most outstanding examples of the trend in railroad specialization is the high-speed unit train, which uses up to 125 high-capacity cars to haul several thousand tons of a single commodity. Unit trains operate on a fast turn-around basis between one or a number of producers and a large consumer. Technological improvements in rolling stock are expected to result in the use of relatively fewer (but higher capacity) cars and thereby adversely affect employment requirements for operating and maintenance personnel. In addition, the trend toward automatic loading and unloading features and containerized freight should reduce the need for materials handling workers. Further labor and other cost savings may be realized from the availability of more durable locomotives and freight cars.

Maintenance labor requirements will also be affected by improved construction materials, better roadway installation, and improved maintenance equipment. For example, improved machines for completely rehabilitating the roadbed and track structure are replacing less automatic equipment introduced in the 1950's. The growing use of electronic hot-box detectors, improved brass bearings and lubricating pads, and roller bearings on freight cars is continually cutting maintenance costs by substantially reducing journal failures. The introduction of sharp flange and dragging equipment detectors is reducing unit maintenance requirements. The development of more durable materials and better construction methods for roadbeds and structures will also tend to reduce maintenance requirements.

One of the most significant improvements in railroad technology in recent years has been the development and rapid growth of "piggybacking." Since 1958, trailer-on-flatcar (TOFC) loadings have increased by more than 200 percent, to about 3 percent of total car loadings in 1964. The expected continuation of this trend, coupled with further TOFC innovations, may have a significant impact on employment in railroad occupations in the decade ahead. Although TOFC transportation increases overall railroad freight activity by diverting long-haul traffic away from highway movement, it reduces unit labor requirements by cutting down on dunnage, freight handling, and clerical activities. Future innovations in TOFC technology will involve design improvements in flatcars and in loading and unloading equipment, as well as additional tunnel and track reconstruction.

Technological innovations in electronic equipment and automatic control systems will lead to greater efficiency of railroad operations by speeding the flow of traffic and increasing equipment utilization. More efficient operations, in general, will permit traffic growth without corresponding increases in employment. For example, the efficiency of car locating and accounting activities could be improved by the use of automatic car identification systems that are being developed to monitor trains and transmit data related to car movements. Improved, higher-capacity, centralized traffic control systems will result in more consolidation of control centers. Labor savings will result directly from the reduced need for towermen and telegraphers. The increasing use of electronic (automatic and semiautomatic) classification yards will substantially reduce the need for yard employees through the combination of facilities.

Advances in communications, and the increasingly widespread application of electronic data processing systems may have the greatest potential impact on railroad transportation service and employment patterns in the years ahead. In the future, many of the automatic systems discussed above may be linked by a central computer and communications system to operate a more highly automated railroad. Apart from the use of computers in automatic classification yards, electronic data processing is now confined largely to payroll and routine accounting and recordkeeping functions. In the future, however, computers will be used for routine decision making, interline accounting, traffic and cost research, and controlling car movements and inventories. The major impact of computer usage in the years ahead will be on office workers, although the future role of computers in automated operations may adversely affect employment requirements for operating personnel.

Local and Suburban Transit and Interurban Passenger Transportation (SIC 41)

Summary

Between 1964 and 1975, little or no change is expected in employment requirements in this major industry group. Employment growth will be limited principally by the lack of growth in passenger traffic on privately operated public transportation systems.

Employment Trends

1958–64. Employment in the local and interurban passenger transportation major industry group declined slightly from 285,000 in 1958 [28] to 267,000 in 1964.

More than 85 percent of total employment in local and interurban passenger transportation is concentrated in three principal industry groups—taxicabs, which account for 41 percent; local and suburban transit, more than 31 percent; and intercity and rural buslines, about 16 percent. Employment of the remaining workers is distributed among charter services, school buses, and terminal and service facilities.

Employment in each of three principal industry groups declined in the post-World War II period. The sharpest decline occurred in local and suburban transit. The number of workers employed in this industry group dropped by nearly three-fifths between 1947 and 1964. Between 1958 and 1964, local and suburban transit employment declined 20 percent. Employment in the taxicab industry group likewise has declined in recent years; more than 9 percent fewer workers were employed in this industry group in 1964 than in 1958. Intercity and rural busline employment declined by about 23 percent between 1947 and 1964. However, employment in this industry has stabilized and increased slightly since 1960. In contrast to the declining trends in the three principal industry sectors, employment in charter services, school buses, and terminal and service facilities, combined, has doubled, increasing from 16,000 in 1958 to 32,000 in 1964, primarily as a result of expanding school-age population.

Declining employment in the local transit and taxicab industry groups was principally the result of increased reliance on private automobile transportation. Widespread public reliance on private automobiles resulted, in part, from the demands of suburban living for a highly flexible means of personal transportation, higher levels of consumer incomes, and improved highways.

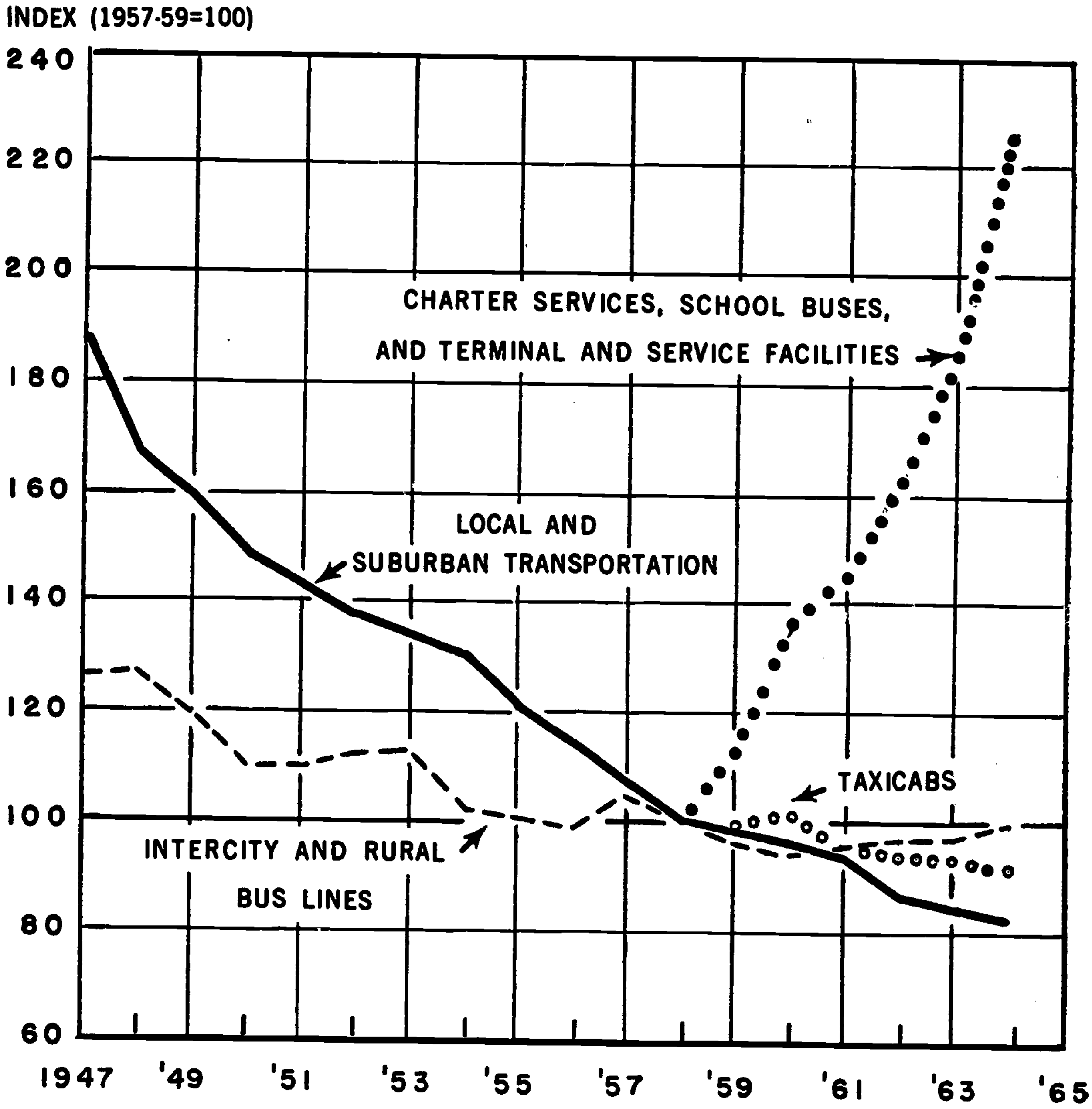
The downward trend in employment in intercity bus transportation was also the result of competition from other modes of transportation, i.e., private automobiles and air carriers. Although there was a dramatic growth in intercity passenger travel during the post-World War II period, intercity bus travel declined both relatively and absolutely. The downward trends in intercity bus traffic and employment, however, appear to have leveled off and slight gains have occurred in recent years largely because of vigorous promotional campaigns by intercity bus companies and improved services to the traveling public.

1964–75. Little or no change is expected in the employment requirements of the local and interurban passenger transportation major industry

[28] BLS employment (payroll) data for the local and interurban passenger transportation major industry group (SIC 41) are not available for the years prior to 1958. Bureau of Labor Statistics employment data for the local and suburban transportation industry excludes workers employed by publicly owned transit systems. Available information indicates that employment in publicly and privately owned transit systems combined declined by about 100,000 workers in the post-World War II period.

EMPLOYMENT IN LOCAL AND SUBURBAN TRANSIT AND INTERURBAN PASSENGER TRANSPORTATION, 1947-64

Employment (in 000's)	
1958	285
1959	281
1960	284
1961	277
1962	271
1963	269
1964	267



Source: Bureau of Labor Statistics

group over the 1964–75 period. Employment requirements in the local transit and taxicab industry groups are expected to remain at about the 1964 level through 1975. In contrast, employment requirements in the intercity bus industry group are expected to increase moderately. Requirements in charter services, schoolbuses, and terminal facilities, are expected to increase, but slower than in recent years.

Employment requirements for local transit and taxicab workers will be adversely affected by the increased use of privately owned automobiles, stimulated in large part by the continued population shift to the suburbs. However, no sharp decline in traffic or employment is anticipated because downtown traffic congestion and parking problems will continue to encourage bus and taxi travel in midtown areas. (The BLS payroll series for this industry group, which includes only privately owned transportation companies, will also be affected by a continuation in the present trend toward publicly owned local transit systems.) In addition, legislation passed in mid-1964, which offers financial assistance to help urban communities alleviate downtown traffic congestion and parking problems, should encourage public use of mass transportation facilities. However, this legislation is not expected to affect total transit employment significantly in the next decade.

The projected increase in the requirements for intercity bus workers will result from a moderate increase in demand for this mode of transportation. Population growth, higher consumer incomes, and more leisure time will result in an increase in intercity travel generally, a portion of which is expected to be by bus. More specific factors expected to increase intercity bus travel include an improved highway system, which will cut scheduled running time; an increasing number of larger and more comfortable buses; and additional deluxe express buses offering hostess service, refreshments, and other conveniences. Bus traffic will also be favorably affected by touring and charter services, and by bus transport of package-express and first-class mail, which has become an important source of carrier revenue in the past several years. The further curtailment or elimination of railroad passenger service in many areas may also be expected to encourage greater use of intercity bus service.

Effects of Technological Developments on Future Employment

Declining employment in the local and interurban passenger transportation industries has resulted chiefly from losses in traffic rather than use of laborsaving innovations. The changes that have occurred in the technology of these industries have been limited largely to the elimination of surface rail (streetcar) transit and the expanded use of improved motor bus and suburban transit equipment. Improved intercity highways have greatly enhanced the comfort, speed, and convenience of bus travel; but corresponding improvements in city streets have been a mixed blessing to local buses and taxicabs because of the private car traffic that has evolved.

Future improvements in the technology of local public transportation will be centered around the development of rapid (rail) transit systems in the larger cities and improvements in bus facilities in many small and medium-sized cities. The development and improvement of local transit facilities in both large and small cities are expected to be accelerated by provisions of the recently enacted Federal legislation mentioned above. The development of rapid transit may limit employment opportunities for bus drivers, as the role of local buses will be reduced largely to providing feeder service to the rail system. In addition, as the maintenance requirements of local transit in some areas shift from motor bus to rail, some bus mechanics will either lose their jobs or be forced to acquire new skills. However, these adverse employment effects in the larger cities could be largely offset by increased employment in the local bus systems of many small- and medium-sized communities.

Many of the rapid transit systems that will be developed over the next decade are expected to be run automatically through the use of computers. Accounting functions, and maintenance and operations scheduling may also be performed largely through use of computers. In addition, ticket sales and collection, and analysis of power equipment functioning could be handled by automatic methods in the future. The use of such equipment will probably limit employment opportunities in many operating, clerical, and maintenance occupations.

In addition to the development of automated rapid transit, demonstration projects are underway to encourage private automobile passengers to use public transportation. These experiments and demonstration projects include special bus service for shoppers, restricted bus lanes during rush hours, variable and multizone fares, and bus service by subscription.

Technological innovations affecting the intercity bus industry will be limited chiefly to improvements in highways and equipment. Progress on the 41,000-mile system of interstate and defense highways, which is now nearly half completed, coupled with the construction of additional toll highways and improvements in other Federal and State roads is not only reducing costs for the motor carriers, but also increasing the comfort and convenience of intercity bus travel. By greatly reducing travel time between points, these improvements in the Nation's highway systems are making motor buses more competitive with air travel, especially on short or medium distance trips.

Equipment innovations in the intercity bus industry will be limited principally to replacing older buses with larger and more comfortable buses now used mainly by large carriers. In addition, the expansion of service innovations, such as buses equipped with washrooms, and refreshment and meal facilities, will increase the efficiency of intercity bus operations by reducing the frequency of stops on long trips.

The overall effect of technological improvements affecting the intercity bus industry group will be to increase passenger traffic and create additional employment opportunities in both road and terminal occupations. In addition, the expansion of on-board passenger services will stimulate the need for a growing number of bus hostesses.

Further in the future, the development of new transportation systems directly competitive with intercity buslines could offset the traffic attracting effects of the interstate highway system and comfort oriented buses. Rapid transportation systems are presently under study that would link such cities as Washington, New York, and Boston with an ultra-high-speed express rail system. Such systems could eliminate a substantial amount of the bus traffic along parallel highways.

Motor Freight Transportation and Storage (SIC 42)

Summary

Employment in the motor freight transportation and storage major industry group is expected to increase rapidly between 1964 and 1975, but slower than during the post-World War II period. Future employment growth is predicated on a steadily rising demand for motor freight services. Technological change is expected to be a significant factor limiting employment expansion in these industries through the mid-1970's.

Employment Trends

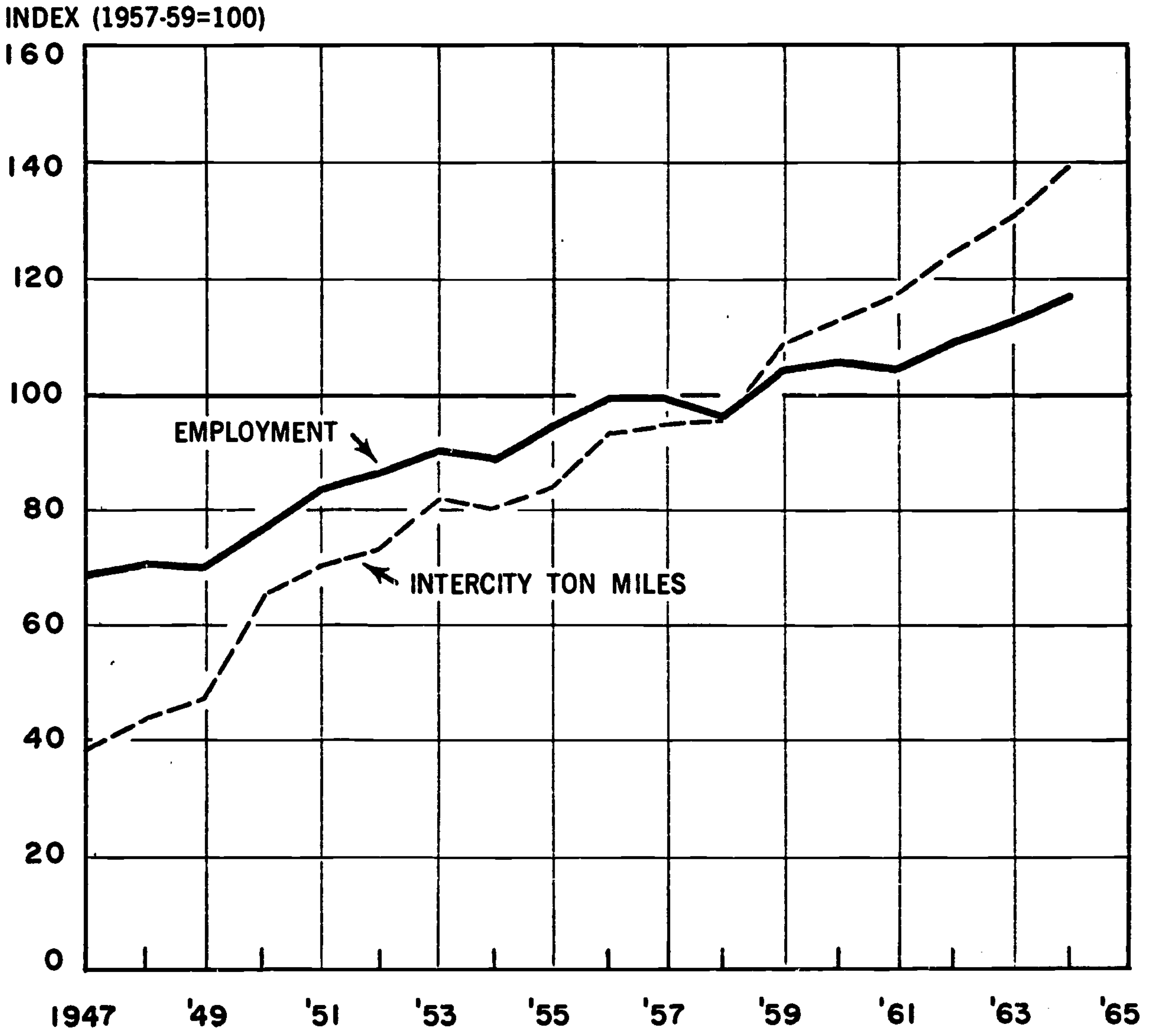
1947–64. Employment in the motor freight transportation and storage major industry group, which includes local and long distance trucking, public warehousing, and terminal facilities, increased rapidly in the post-World War II period. Employment in the motor freight major industry group rose steadily from 551,000 workers in 1947 to nearly 920,000 in 1964, a two-thirds increase.

The growth of trucking employment resulted from a rapid growth in motor carrier activity. Between 1947 and 1964, the number of intercity ton-miles accounted for by all private [29] and for-hire motor carriers increased by over 250 percent. Over the same period, the number of intercity ton-miles for all carriers of freight (rail, truck, pipeline, water, and air) increased by about 50 per-

[29] Bureau of Labor Statistics employment data for this major industry group include only workers employed by for-hire motor carriers. However, the increase in total activity is an indicator of the trend in for-hire motor carrier activity.

EMPLOYMENT AND INTERCITY TON-MILES IN MOTOR FREIGHT TRANSPORTATION AND STORAGE, 1947-64

Employment (in 000's)	
1947	551
1948	573
1949	567
1950	619
1951	676
1952	699
1953	731
1954	719
1955	765
1956	803
1957	804
1958	778
1959	844
1960	856
1961	845
1962	885
1963	904
1964	920



Sources: Data on employment, Bureau of Labor Statistics; intercity ton-miles, Interstate Commerce Commission.

cent. In 1947, private and for-hire truck operators accounted for only 10 percent of all intercity freight movements (measured in ton-miles); by 1964, the trucker's share of the market had increased to nearly 24 percent. Growth of trucking employment also was stimulated by the expansion of local freight volume, since trucks carry virtually all freight for local distribution. Local trucking employment has also been favorably affected by the rapid increase in the number of suburban shopping centers and by industry relocation to the suburbs.

Although employment in the motor freight major industry group has expanded rapidly, growth has been limited by improvements in the technology affecting this industry. The most significant of these improvements are concerned with the vehicle itself and the condition of the roads on which it operates. The capacity of motor vehicles of a given size has been increased considerably through use of lighter-weight materials and improved vehicle design. As a result of physical improvements in our Nation's roadways, including reductions in highway curvature and grade and the bypassing of cross traffic through use of overpasses, the legal size, weight, and speed maximums of motor vehicles have been raised in many States. As a result of vehicle and highway improvements, the average annual ton-miles per motor vehicle operated by regulated motor carriers has increased by about 50 percent during the post-World War II period.

1964–75. Employment requirements in the motor freight transportation and storage major industry group are expected to increase from about 920,000 in 1964 to approximately 1.2 million in 1975, an increase of about 30 percent.

The demand for motor freight transportation services is expected to increase rapidly as a result of the anticipated high level of economic activity. Intercity motor freight activity, however, is not expected to continue to increase as rapidly as it has in the past because of changing competitive conditions. The diversion of high value commodity traffic from rail to truck by means of lower freight rates can no longer be expected to contribute to motor carrier expansion. Today, in their efforts to retain existing traffic and recover movement of commodities formerly carried, railroads are placing increasing emphasis on reducing costs. Motor carriers are also facing increasing competition from air carriers for the movement of high value traffic. In addition, the flexibility of movement provided by public highways is an advantage no longer restricted to the motor carrier. Through use of containers on wheels, other types of carriers can now provide direct freight services to customers who are far removed from their rail, water, or air facilities.

The demand for local trucking services, which is not affected by similar competitive factors, is expected to increase with the anticipated rapid growth in the total volume of freight moved in the economy. Motor trucking will continue to be the predominant method for distributing goods within local market areas, and employment in local trucking should grow rapidly in the years ahead.

Effects of Technological Developments on Future Employment

Changing technology will significantly increase output per worker in nearly all occupational areas of the motor freight transportation and storage major industry group. The changing nature of our system of highways and the laws governing their use make up a significant part of the changing technology of the motor freight industry. The 41,000-mile system of interstate and defense highways, which is now about half completed, will continue to increase the efficiency of motor carrier operations by reducing running time, and cutting maintenance and accident costs. The completion of this system of divided, limited-access highways, and the construction of toll throughways and improvements in other Federal and State roads, is expected to result in increased legal size and weight maximums of vehicles. The effect of these changes will be to limit the employment growth of truckdrivers by reducing manpower requirements per unit of freight carried.

Many technological innovations are directed toward improving the operating efficiency of commercial vehicles. Design innovations in the construction of trucks, truck-tractors, and trailers are resulting in increased payload capacities without corresponding increases in the dimensions or loaded weight of the vehicle, through the use of lighter weight materials, such as aluminum or fiberglass. The development of improved gasoline and diesel engines will also contribute to the greater efficiency of commercial vehicles. These new power plants will be smaller and lighter, yet more powerful and provide greater fuel economy than their predecessors. These innovations, which increase the capacity and efficiency of commercial vehicles, will likewise limit growth in the number of truck drivers by increasing the size of the average load hauled per vehicle.

Technological advances in the motor trucking industry may also affect employment requirements for maintenance personnel. Many of the new gasoline and diesel engines now under development will have greatly reduced maintenance requirements. Innovations in vehicle design will also facilitate maintenance by making vital mechanical and electrical components more easily accessible. In addition, a growing number of carriers with large truck fleets are using sophisticated test equipment, such as spectrometers for engine oil analysis, to forestall costly breakdowns.

Along with technological improvements in general freight vehicles, progress is being made in development of specialized equipment to handle a wide range of commodities that cannot be handled efficiently in conventional packaged-freight containers. Among the more notable innovations in specialized trucking are improved refrigeration and insulation systems for maintenance of extremely low temperatures, bulk carriage containers with pneumatic loading devices, and convertible and collapsible tanks that can be adapted for use in a wide range of liquid and dry hauling. Other innovations include vehicles with special features for loading and unloading heavy or cumbersome freight, and vehicles with adjustable trailers for moving military hardware and heavy machinery. Since special equipment innovations are designed to help motor carriers compete for a wider range of commodities, they tend to increase employment requirements by contributing to overall motor freight traffic growth.

The changing technology in trucking is not confined to innovations in motor vehicles. The increasing size of motor freight companies is accelerating the rate of technological change in modern terminal operations. Major consolidating terminals are becoming larger and more efficient, but fewer in number. One of the most significant features contributing to this increased efficiency is an automatic dragline system for channeling freight between 100 or more freight docks within a terminal. The use of this system greatly reduces manpower requirements for freight handling personnel. An important innovation in modern terminal operations is the use of cargo cages for combinging less-than-truckload shipments. These devices greatly reduce labor requirements for handling small shipments. Freight handling by some of the larger carriers is also expected to be expedited by the use of data processing systems that improve office operations and reduce unit labor requirements for clerical personnel.

The development of standardized freight containers is resulting in their increasing use by all modes of transportation. This development eliminates multiple handling of packaged freight to and from truck and rail, water, and air carriers. The use of standardized freight containers reduces damage to shipments and claims for damage, and permits more rapid dispatch of freight, thereby adversely affecting requirements for freight handlers and checkers (clerks).

Transportation by Air (SIC 45)

Summary

Employment requirements in the air transportation major industry group are expected to increase rapidly between 1964 and 1975. Future employment growth is predicated on a rapid rise in passenger and cargo traffic. Technological change is expected to be a significant factor in limiting employment growth in air transportation through the mid-1970's.

Employment Trends

1958–64. Employment in air transportation expanded rapidly between 1958 and 1964, increasing by nearly 30 percent from 165,000 workers to 213,000 over the period.[30] During the same period, surface transportation employment declined slightly.

In 1964, about 90 percent of employment in air transportation was accounted for by air common carriers, which provide for-hire air transportation to the public. The remaining workers were employed at airport terminals and by operators of airports and flying fields.

Between 1947 and 1958, employment by air common carriers increased from 82,000 to 149,000 workers, a gain of 82 percent over the period. Since 1958, air carrier employment has risen nearly 30 percent, to 192,000 workers in 1964. Over this latter period, employment in fixed facilities and related services, airports, flying fields, and terminals, increased by 34 percent.

The dramatic post-World War II growth in air traffic activity, particularly among the scheduled airlines,[31] was primarily responsible for the rapid expansion in air carrier employment. Between 1947 and 1964, the number of revenue passenger miles and revenue ton miles flown by certificated route air carriers in scheduled service increased by 640 and 700 percent, respectively. Over the same period, available seat miles increased by over 750 percent, and available ton miles by nearly 850 percent.

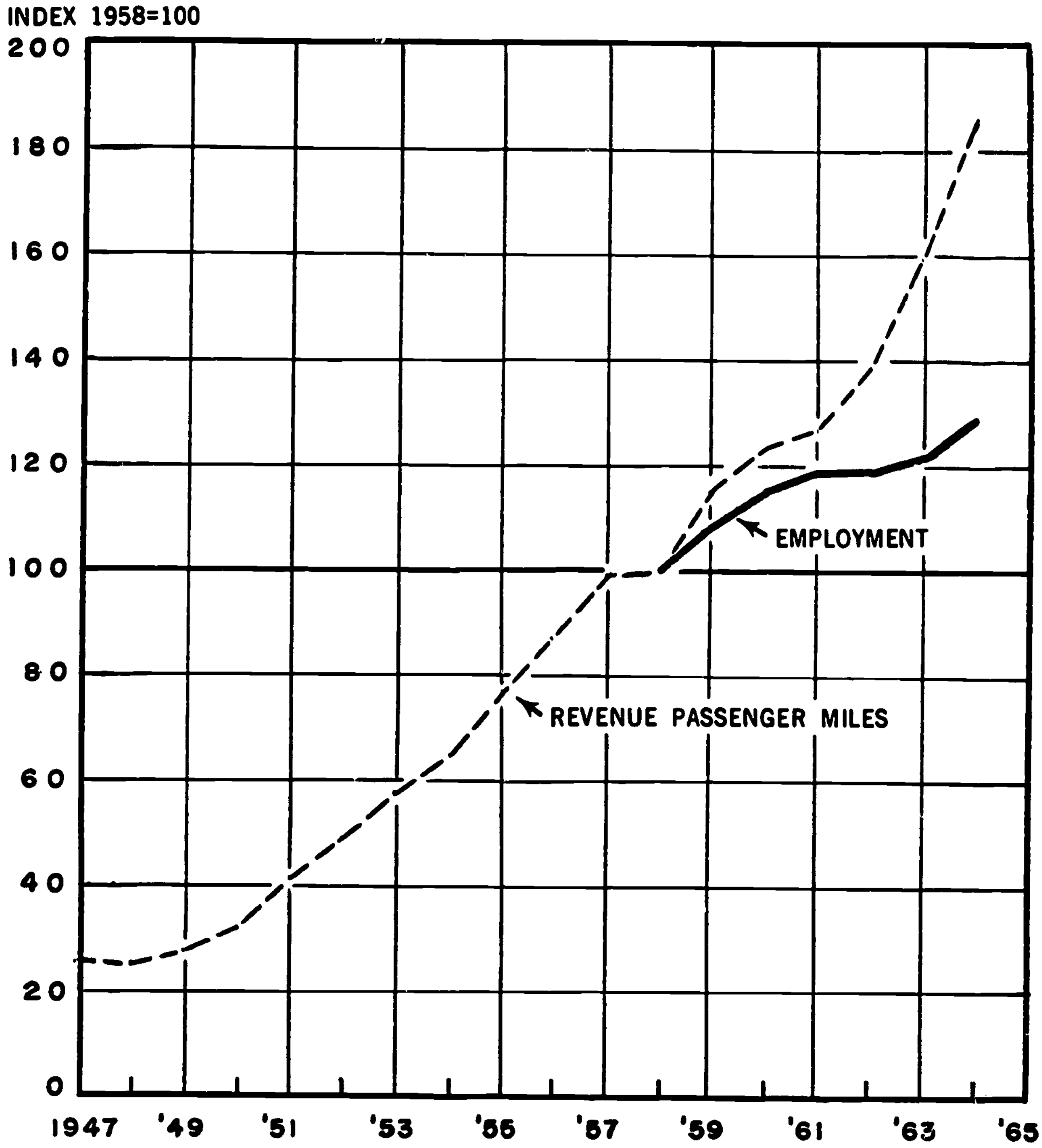
The airlines have been able to expand their activities several times faster than employment chiefly by utilizing more efficient aircraft and ground operations equipment. In recent years,

[30] BLS employment (payroll) data for the air transportation major industry group are not available for the years prior to 1958.

[31] A comparison of Bureau of Labor Statistics and Federal Aviation Agency employment data shows that the scheduled airlines account for about 85 percent of total employment in this major industry group.

EMPLOYMENT AND REVENUE PASSENGER MILES IN AIR TRANSPORTATION, 1947-64

Employment (in 000's)	
1958	165
1959	179
1960	191
1961	196
1962	197
1963	202
1964	213



Sources: Employment, Bureau of Labor Statistics; revenue passenger miles, Federal Aviation Agency

the airlines have been replacing piston powered aircraft with faster and higher capacity turbine powered aircraft. On the ground, computers and other electronic and mechanical devices have been used to improve communications, data processing, flight planning, and aircraft and traffic servicing.

Employment at airport terminals and in fixed base operations has expanded with the general rise in air traffic. Fixed base employment has also grown with the increasing activity in business flying and other segments of general aviation.

1964–75. Employment requirements in the air transportation industry are expected to increase rapidly through the mid-1970's. The number of workers employed in this industry may exceed 300,000 by 1975, more than 40 percent higher than the 213,000 workers employed in 1964. Air common carrier employment is expected to increase at a rate of about 3.3 percent annually between 1964 and 1975, compared with an average growth rate of over 5 percent between 1947 and 1964.

The rapid growth in employment requirements projected for this industry are expected to result from an ever expanding demand for air transportation services, both passenger and cargo. The major stimulus for this growth in air traffic will come from rising consumer and business incomes, an expanding population, and increasing amounts of leisure time. In order to meet this growing demand for air travel and to take advantage of the high profit potential of modern turbine-powered aircraft, the airlines today are placing record numbers of equipment orders, both for additions to their fleets and for the replacement of a number of aging piston aircraft. Equipment improvements, in providing greater speed and comfort to airline passengers, may contribute to an even greater volume of traffic than anticipated.

In addition to the anticipated growth in passenger activity, the use of more efficient turbine powered aircraft in cargo operations is expected to stimulate freight traffic through reduced rates and improved service. Future growth in air traffic is also expected to result from the extension of air freight services to many small- and medium-sized communities through the local service airlines.

Effects of Technological Developments on Future Employment

Continued improvements in air transportation technology are expected to partially offset expanding passenger and cargo traffic in the next decade. One of the most significant developments will be the replacement of piston aircraft with more efficient turbine powered aircraft. The conversion to an all-turbine airline fleet, which is expected to be accomplished by the early 1970's, will allow the airlines to absorb a growing volume of traffic with little or no increase in fleet size or in the employment of flight deck or maintenance personnel.

Many of the new second generation jets scheduled for service in the late 1960's will be short- and medium-range passenger planes. Some of these aircraft will have interiors that can be easily converted into use for either passenger or cargo service. The development of these short- and medium-range jets will increase the efficiency of the airlines by complementing the long-range jets in the fleets of the large domestic and international carriers and by providing appropriate range turbine aircraft for use by local service carriers. Other second-generation jets which will go into service in the late 1960's include longer range and higher capacity versions of the passenger and cargo jets now in service throughout the industry.

In the mid-1970's, the airlines are expected to put in service one or more of a number of highly productive aircraft now under development. Foremost in this development is a supersonic transport, which will operate over long distances at speeds up to 2,000 miles per hour. An alternative to this medium capacity supersonic transport is a subsonic transport with a capacity of 500 to 700 passengers or 250,000 pounds of cargo. The latter approach to increasing the efficiency of the jet transport would involve increasing the size of the aircraft rather than its speed. Development of the supersonic aircraft appears to be favored over the slower, heavier aircraft since use of the latter would probably require stronger runways and expanded terminal facilities.

Another aircraft that may become operational in the next decade is a high-passenger-capacity vertical takeoff and landing aircraft that will operate between cities of up to a few hundred miles apart and between metropolitan centers and airports. Such aircraft could provide downtown to downtown travel between nearby cities and greatly reduce travel time spent getting to and away from airports on longer flights. General acceptance of this mode of travel could create additional requirements for flight personnel.

Technological innovations in aircraft will also have a significant impact on the rapidly growing air cargo sector. Improvements in air cargo technology will lead not only to greater efficiency of operation, but also may favorably affect employment by accelerating the growth in traffic. Much of the expected growth in air freight activity will result from the availability of service to an increasing number of communities and from anticipated rate reductions stemming from the use of more efficient cargo transport. Both the all-cargo and combination carriers also can be expected to convert their cargo fleets to all-turbine operations due to the cost and speed advantages of jet over piston aircraft. This fleet of turbine aircraft will be made up largely of cargo carrying versions of jet aircraft developed for passenger service. In addition, a civilian version of a large military freighter is presently available, and a similar but higher capacity model will be ready for service in a few years. In addition to larger and faster cargo transports, air freight operations will be improved by the use of more efficient cargo handling and loading equipment. This new ground equipment will tend to limit the growth of employment requirements for freight-handling personnel.

Technological improvements are also anticipated in flight control and guidance systems. The most significant developments in this area will be a fully automated air traffic control system, a flight navigation system requiring no contact with ground stations, and an all-weather landing guidance system. Use of this automatic equipment may reduce employment requirements for air traffic control personnel, who are employees of the Federal Government. The overall impact of these new systems on employment within the air transportation industry, however, is likely to be favorable, as they are expected to make air travel more attractive through increased safety and dependability. These new flight control and guidance systems will permit more flight traffic and will facilitate closer adherence to flight schedules, even during unfavorable weather conditions.

The air transportation major industry group is expected to use many of the most advanced electronic control and data processing systems in the future. The automated air traffic control and all-weather landing systems projected for the 1970's will be built around computers and other sophisticated electronic equipment. Many of the new air transports now under development may, in effect, be flown by pilot monitored computers. Today, electronic computers are already important tools in base operations of many domestic and international airlines. These computers are used increasingly in maintenance and inventory control, accounting and flight planning, and in processing passenger reservations among carriers. The continued application of computer technology in air transportation will limit employment opportunities chiefly among traffic agents and clerical workers.

Communications (SIC 48)

Summary

Employment requirements in communications are expected to increase slightly during the decade ahead. Although demand for communications services is expected to rise rapidly, technological innovations will tend to limit growth in employment.

Employment Trends

1947–64. Estimated employment in the communications major industry group increased by 31 percent between 1947 and 1957; [32] however, between 1957 and 1964, employment declined about 6 percent. Employment was spurred during the early post-World War II period by the rapid rise of television broadcasting and the increased use of telephone communications. The period of declining employment resulted in part from the growing use of technological laborsaving devices and the decreasing utilization of telegraph communications.

Telephone communications is the largest communications industry group. In 1964, about 83 percent of all communications workers were employed by companies providing telephone services. The remaining workers were employed in radio broadcasting and television (12 percent), telegraph communications (4 percent), and communications services not elsewhere classified (about 1 percent).

Employment growth rates varied widely among the communications industry groups in the post-World War II period. Employment in radio broadcasting and television, spurred by the extremely rapid growth of television—in its infancy in 1947—increased more than 1½ times between 1947 and 1964. In sharp contrast, employment in telegraph communications declined more than 45 percent during the same period, primarily because of increased use of competing services such as airmail, telephones, and data transmission by telephones.

Employment in telephone communications increased by 21 percent from 1947 to 1964, rising from 586,000 in 1947 to 706,000 in 1964. All of the increase occurred before 1957 when employment reached its all time high—768,000—more than 30 percent above the 1947 level. The employment expansion from 1947 to 1957 reflected the rapid growth of telephone services, resulting in part from the backlog accumulated during World War II. In 1958, employment in telephone communications turned downward, and by 1964 was about 8 percent lower than in 1957, even though a moderate increase occurred in 1964. The demand for telephone services continued its upward trend from 1957 to 1964, but the rate of increase was not as great as in the early postwar period. In addition, rapid technological changes, which greatly increased the efficiency of the work force, in a large part accounted for the failure of employment to rise in the later period.

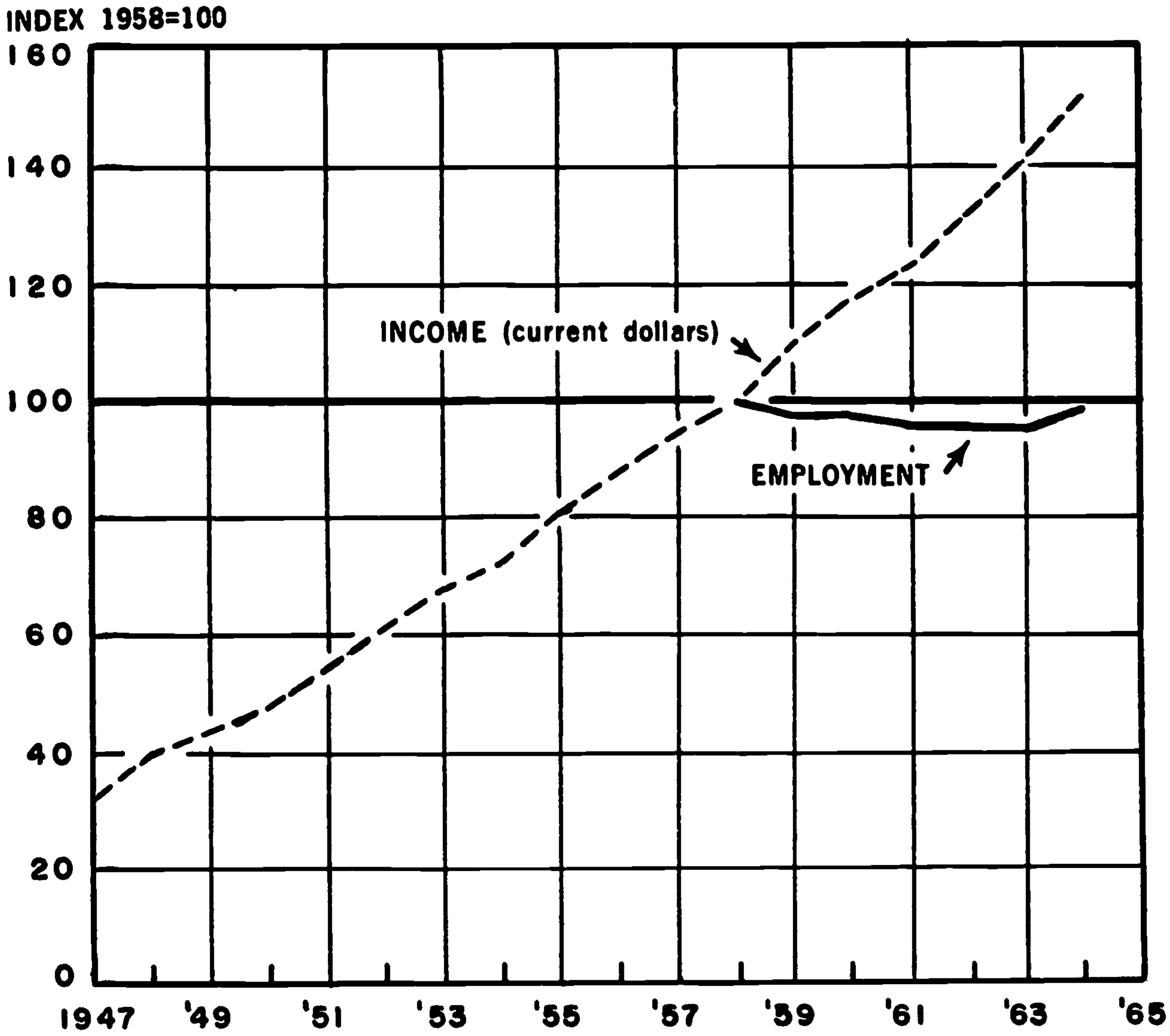
1964–75. Manpower requirements in the communications major industry group are expected to rise slowly between 1964 and 1975, reaching 875,000 by 1975. Employment trends for the individual industry groups, however, are expected to differ widely because of differences in demand and the impact of technological developments.

As in the past, manpower requirements in telephone communications will be affected both by rapid increases in the demand for telephone services and by laborsaving technological innovations. These largely offsetting trends are expected to result in a slight increase in employment requirements between 1964 and 1975. The demand for telephone services will be accelerated by increases in household formations, and the growing number and size of business and industrial establishments.

[32] BLS establishment (payroll) data for the overall communications major industry group are available only for the years 1958–64, because of the exclusion of the radio broadcasting and TV industry group prior to 1958. However, 1947–58 BLS establishment data are available for the telephone and telegraph industries, which employed 87 percent of total employment in the communications major industry group in 1964. These data for 1947–57, were aggregated with unemployment insurance data for the broadcasting industry for the same years to provide estimates of employment trends for the total major industry group between 1947 and 1957.

EMPLOYMENT AND NATIONAL INCOME ORIGINATING IN COMMUNICATIONS, 1947-64

Employment	(in 000's)
1958	860
1959	837
1960	840
1961	829
1962	824
1963	824
1964	848



Sources: Employment, Bureau of Labor Statistics; national income, Office of Business Economics.

Many of the 11 million households now without telephones, but who are expected to add telephone service will be another factor in the rising demand, especially as family incomes rise. Demand will be further increased by the development of new and improved services such as high-speed transmission of data by telephone, pushbutton dialing, conference dialing, picturephones, speakerphones, and the growing use of extension and multicolored telephones in the home.

A moderate increase is expected in manpower requirements in the radio and television broadcasting industry. Although the rise will not be as great as in the past, continuing increases in the number of radio and television broadcasting stations are expected to raise employment requirements despite the introduction of many laborsaving technological developments. The downward trend in employment in telegraph communications is expected to continue through 1975, as strong competition from telephones, data transmission by telephone, and airmail services continue.

Effects of Technological Developments on Future Employment

Technological changes are expected to be particularly significant in telephone communications. The conversion to automatic dialing for local calls is virtually complete, but a greater percentage of directly dialed and automatically billed, long-distance calls is expected. The installation of traffic service position equipment will increase the efficiency of operators by enabling them to handle quickly service calls such as person-to-person, pay station, and collect calls. Two additional innovations, a fully automatic system to handle intercept calls (disconnected numbers, etc.) and a computerized system for information calls, are still in the developmental stage and their impact on operator employment may be minimal by 1975.

Computers, which have already gained widespread use in telephone communications, are expected to be used more extensively through 1975. Computer applications now include accounting, billing and collecting, traffic and plant planning, supply operations, and equipment ordering, and are expected to include directory composition, as well as the answering of information and intercept calls. The displacement impact of computers is greatest among clerical workers, but other occupations will also be affected.

Another significant innovation is electronic switching equipment that offers considerable savings in maintenance labor. Not only is this electronic system programed to analyze itself and point out the nature and location of malfunctions, but much of the repair work on the electronic systems can be made with module and plug-in units that simplify repair jobs. Duplicate circuits enable the equipment to operate during minor breakdowns and service changes can be made by changing the circuit "memory," eliminating the altering and rewiring necessary with present switching equipment.

Continuing technological improvements are also expected in transmission equipment. The use of microwave radio relay systems, which have greater capacity than cable systems, is expected to grow, thereby reducing the need for cable splicers, linemen, and other workers involved in the construction and maintenance of transmission lines. In the future, a considerable proportion of the circuits needed to handle the rapidly increasing volume of telephone calls will be met by increasing the capacity of existing facilities through pulse code modulation, rather than by constructing new coaxial cables and microwave facilities, leading to substantial reductions in the number of construction workers. The requirements for cable splicers will continue to be reduced by the use of polyethylene cable, which reduces the time needed for splicing; ready access terminals; instruments for identifying types of wires in cables; and the use of gas-filled cables, which allows failures to be easily located. These developments have already led to the virtual elimination of cable splicer helpers. New transmission facilities may include communication satellites (especially for overseas use), lasers, and helical wave guides.

Improved technology and installation practices are expected to limit growth in employment of installation and exchange repairmen. The use of plug-in equipment speeds the installation of telephones by reducing both the number of wires to be connected and the number of soldered connections. The prewiring of structures permits the faster installation of telephones. The disconnecting of lines in the central office, leaving the telephone lines and equipment in place when customers move, allow for much faster service changes. All of these are now common industry practices, but they will have a cumulative and recurring effect on employment of installers and exchange repairmen, as a larger proportion of units are serviced by these methods.

Substantial technological innovations are also expected in radio broadcasting and television. Remote transmitter control makes it possible to direct the operation of the transmitter tower from the broadcasting studio, thus eliminating the need for broadcasting technicians at the tower. Automatic programing equipment in radio broadcasting, including taped recordings and announcements, makes it possible to operate a radio station on a 24-hour basis with very few full-time employees. The rapid growth in the use of film and videotape materials in television reduces employment in television stations. Both recorded radio programs and taped television shows create jobs in the studios producing the programs, but their net impact is a manpower reduction. An expected growth in CATV (community antennae television) makes it possible to relay programs to areas which were formerly inaccessible, thus reducing the opportunity for new stations in these areas.

Technological changes are also occurring in telegraph communications. A transcontinental microwave system capable of handling an increased number of telegraph messages is now in operation. The microwave system will lead to decreases in the number of linemen, cable splicers, and other personnel involved in constructing and maintaining telegraph lines. Other developments include a high-speed electronic switching system, additional private line facilites, and modern dispatching centers.

Electric, Gas, and Sanitary Services (SIC 49)

Summary

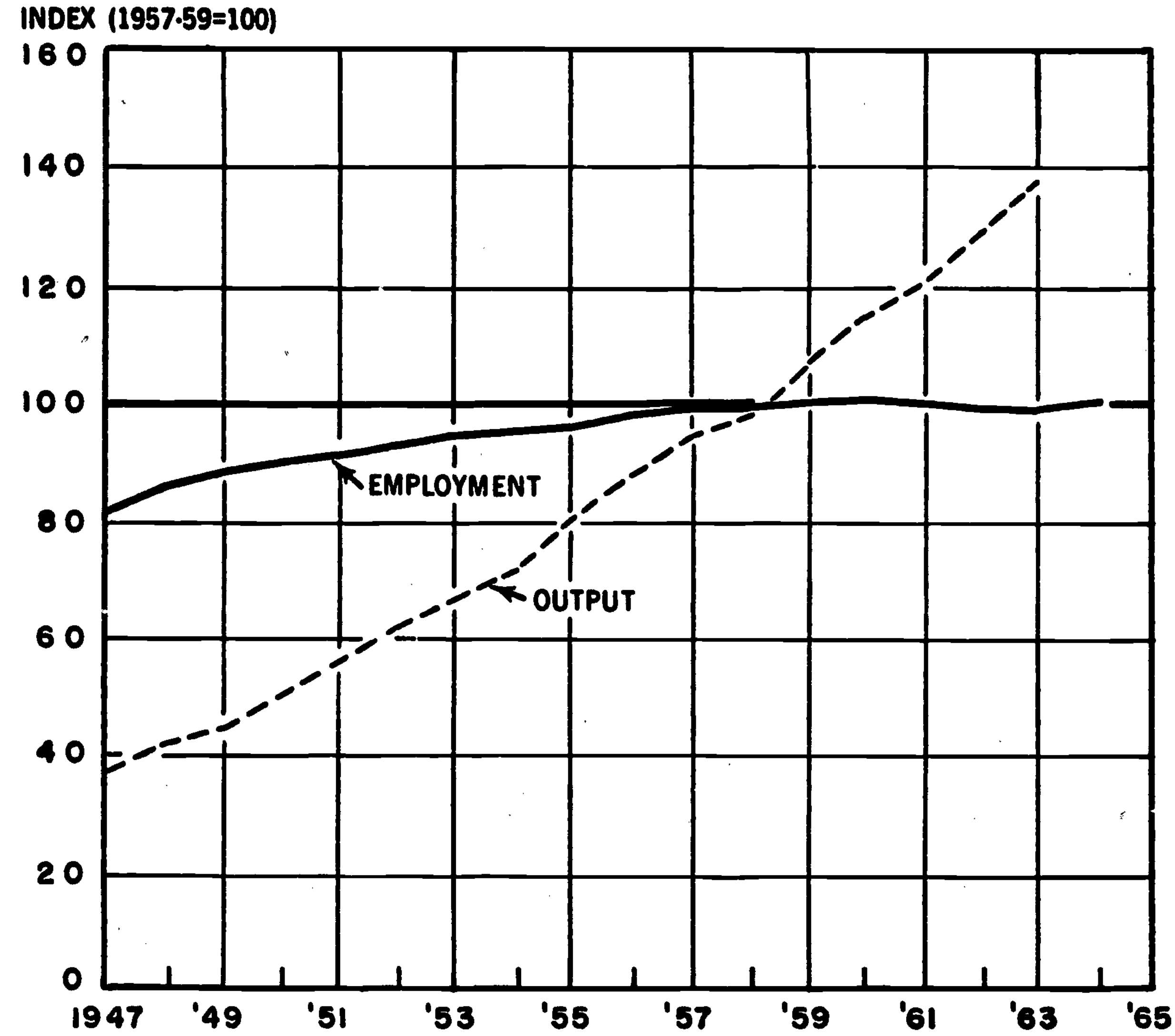
Employment requirements in electric, gas, and sanitary services are anticipated to remain at about the 1964 level through 1975, maintaining the stability that has characterized this major industry group since 1957. The rapid increase anticipated in industry activity is expected to be almost offset by rising output per worker.

Employment Trends

1947–64. Employment in electric, gas, and sanitary services increased from about 498,000 in 1947

EMPLOYMENT AND OUTPUT[1] IN ELECTRIC, GAS, AND SANITARY SERVICES, 1947-64

Employment	(in 000's)
1947	498
1948	527
1949	544
1950	554
1951	561
1952	572
1953	582
1954	585
1955	591
1956	601
1957	611
1958	610
1959	612
1960	615
1961	614
1962	610
1963	610
1964	614



Source: Bureau of Labor Statistics.

[1] The output data are limited to electric, gas, and combination utilities. Output data are not available for water, steam, and sanitary services. However, electric, gas, and combination utilities include 94 percent of employment in the major industry group.

to 614,000 [33] in 1964. Almost all of the increase occurred before 1957 when employment reached about 611,000. Since 1957, employment has remained stable, ranging between 610,000 and 615,000.

This major industry group includes three large industry groups—electric companies and systems (electric utilities), which had about two-fifths of employment in 1964; gas companies and systems (gas utilities) which employed about one-fourth; and combination companies and systems (combination utilities) which accounted for about 30 percent. The remaining workers (about 6 percent) were employed in four smaller industry groups—water supply, sanitary services, steam companies and systems, and irrigation systems.

Although employment in each of the industry groups increased during the post-World War II period, the rates of growth varied considerably. Employment in electric utilities increased by almost 17 percent between 1947 and 1964. Employment in electric utilities reached its highest point in 1957 and decreased slightly (about 4 percent) since that time. The number of workers in gas utilities increased by about 30 percent between 1950 [34] and 1959 and has remained relatively stable since 1960. Employment in the combination utilities sector has shown little change since

[33] Workers employed by Federal, State and local government agencies or departments providing the services of this major industry group are not included in the employment data. This exclusion is particularly important in the water supply, sanitary services, steam companies and systems and irrigation systems industry groups as over 70 percent of the workers in these groups (combined) in 1960 were employed by Government agencies.

[34] BLS employment (payroll) data for the gas and combination utilities industry groups are not available for the years prior to 1950.

1950, ranging between 169,000 and 176,000. Combined employment in the four smaller industry groups increased rapidly from 1957 to 1964 after remaining relatively stable from 1947 to 1957.

Employment in electric and gas utilities[35] has not responded significantly to a rapid expansion in output in recent years. Output increased by 265 percent between 1947 and 1963, while employment increased by only 23 percent—reflecting the rapid increases in output per man-hour which occurred during this period. Output per man-hour increased at an average annual rate of 7.5 percent from 1947 to 1963—more than double the rate of increase in our total private economy. The low relationship between output and employment has been particularly evident since 1957, as output increased by almost 47 percent between 1957 and 1963 without any appreciable change in employment.

1964–75. Employment requirements in the electric, gas, and sanitary services major industry group are expected to be about 625,000 in 1975. The very large increase anticipated in industry activity is expected to be almost offset by rising output per worker.

Demand for the industries' services will be stimulated by increases in population and family formations. Growth in the number of appliances, and gas and electric air conditioning and space heating will lead to greater consumption per residential customer. Industrial and commercial consumption of gas and electricity is expected to continue its upward trend because of business expansion and, in the case of electricity, the growing use of computers, electronic controls, and other electrical and electronic equipment that increases the amount of electricity used.

Employment trends for the electric, gas, and sanitary services industry groups are expected to vary. A small employment decrease is expected in electric utilities, continuing the very slow downward trend that started in 1957. Output of electric power is expected to double by 1975, but in terms of employment, will be almost offset by the very rapid pace of laborsaving technological innovations. Employment in gas utilities is expected to increase somewhat, mainly as a result of expected rapid output gains, but technological developments will limit employment growth. Employment in combination utilities is expected to remain at about the 1964 level through 1975. Rapid employment growth is expected in the four smaller industry groups combined, but because of the small size of these industry groups the number of additional workers required will not be great.

[35] The analysis in this paragraph is limited to electric, gas, and combination utilities, as comparable output data are not available for water, steam and sanitary services.

Effects of Technological Developments on Future Employment

Technological developments are expected to have a significant effect on the number and characteristics of jobs in electric and gas utilities through the mid-1970's.

One major development in electric utilities is the increasing use of computers, both for clerical operations and plant operations such as data logging and equipment regulation. The major occupational impact of computers will be to reduce the need for clerical workers and for plant operators. Conversely, the use of computers will increase the need for programers, systems analysts, console operators, and other computer related personnel.

Substantial improvements in electric generating plant equipment are also expected. These improvements will result in increasing size and efficiency of turbines and boilers. In 1950, the largest available turbine had a maximum rating of 208 megawatts; by 1960, 450-megawatt units were available; in 1965, a 1,000-megawatt unit was in operation and 1,500-megawatt units are expected to be practical in the future.[36] Increases in size will be accompanied by higher operating pressures and temperatures, faster generator speeds, and modernization in the design of boiler-turbine-generator sets. The larger, more efficient units probably will be operated by about the same number of personnel as the smaller units. Special purpose generators, including gas turbines, diesel generators, and hydroelectric reservoirs, will be used to a greater extent to meet peak load requirements. These generators are usually remotely controlled and require no additional operating employees.

Another significant development in electric plant operations is the growing use of electronic controls. In an increasing number of generating plants, operating processes are located in a central control room where electronic instruments record the operations of boilers, turbines, generators, auxiliary equipment, and other plant equipment. In these advanced plants, the control room operator and his assistants perform the duties formerly done by turbine operators, boiler operators, switchboard operators, auxiliary equipment operators, and their assistants. A few of the newer generating plants in operation are completely controlled by electronic computers. Automatic load dispatching equipment, which efficiently allocates generating capacity to meet load requirements, also is being used increasingly.

The growing use of computers, complex electronic instruments, and larger generating units can be expected to lead to increases in the number

[36] *National Power Survey*, a report by the Federal Power Commission, 1964, Vol. I, p. 14 and Vol. II, p. 57.

of maintenance workers employed by electric utilities. The high initial cost of the equipment, plus the considerable cost to the company when the equipment is not in operation, places a premium on preventive maintenance. The skills of the maintenance workers will need to be upgraded, especially their knowledge of electronics, in order to repair the complex equipment.

Coal-handling techniques in electric utilities are being modernized. Developments include rotary dumps for unloading coal trains and high-speed conveyor belts to carry the coal to the generating units—leading to reductions in the employment of coal-handling laborers.

The remote reading of electric and gas meters from a central location through the use of electronic instruments is now under intensive development; preliminary tests have proven successful. Widespread use of remote meter reading could lead to substantial reductions in the number of meter readers—one of the largest occupations in gas and electric utilities.

Technological advances are also occurring in the construction and maintenance of transmission lines. The key development is the aerial lift truck, which lifts the lineman and his tools to the lines and also provides a platform from which the lineman can work. Aerial lifts are often accompanied by hydraulic rotating derricks, winches, pole grabbers, hole-digging equipment, air impact wrenches and drills. The use of this equipment has led to a reduction in the size of a typical line crew from five or six men to three men, with the groundman (laborer) often being completely eliminated. A growing volume of line construction work, spurred by the development of high voltage lines that are capable of carrying power over long distances, will add to future employment in line occupations, in spite of the growing proportion of line construction that is being contracted to companies specializing in this type of work.

An increasing use of nuclear power to generate electricity is another change that should affect the occupational distribution in the electric utility industry. Nuclear plants will require a more specialized operating staff, with expected increases in professional and technical workers. In addition, nuclear equipment requires more maintenance than conventional equipment, so the number of maintenance workers should increase.

The growth of interconnections is expected to increase the efficiency of electric utilities in future years. Interconnections permit the more efficient utilization of generating capacity, as peak load requirements and sudden demands for power in one area may be met by borrowing power from an area where demand is lighter—allowing a considerable reduction in peak load manpower requirements. In addition, interconnections permit smaller utilities by combining needs and facilities to take full advantage of the economy offered by large generating units and modern technology. The growth of interconnections encourage the building of large generating plants using the latest in electronic and computerized technology in locations far remote from the distribution. Such plants are increasingly being built near coal mines and other power sources with the power being carried over high-voltage lines to the distribution point. One result of this change is to transfer electric utility employment from metropolitan areas to the more remote areas.

Substantial technological innovations are also occurring among gas utilities. Computers are being used increasingly for dispatching, accounting, billing, and collecting, reducing the need for clerical workers and gas dispatchers. Automatic monitoring and remote control of pipeline operations is another significant development. Compact compressor stations powered by gas turbines, which are less costly to install, easier to maintain, and more adaptable to remote control than reciprocating engines, are growing in use, reducing the need for maintenance workers and compressor operators. Underground storage facilities and the liquification of natural gas, which reduces a large volume of gas to a small volume of liquid, provides gas reserves at the consumption point. Other developments include more powerful compressors, larger and higher pressure pipelines, and automatic welding to join pipelines—all enabling expanded production without corresponding employment increases.

Wholesale and Retail Trade (SIC Division F)

Summary

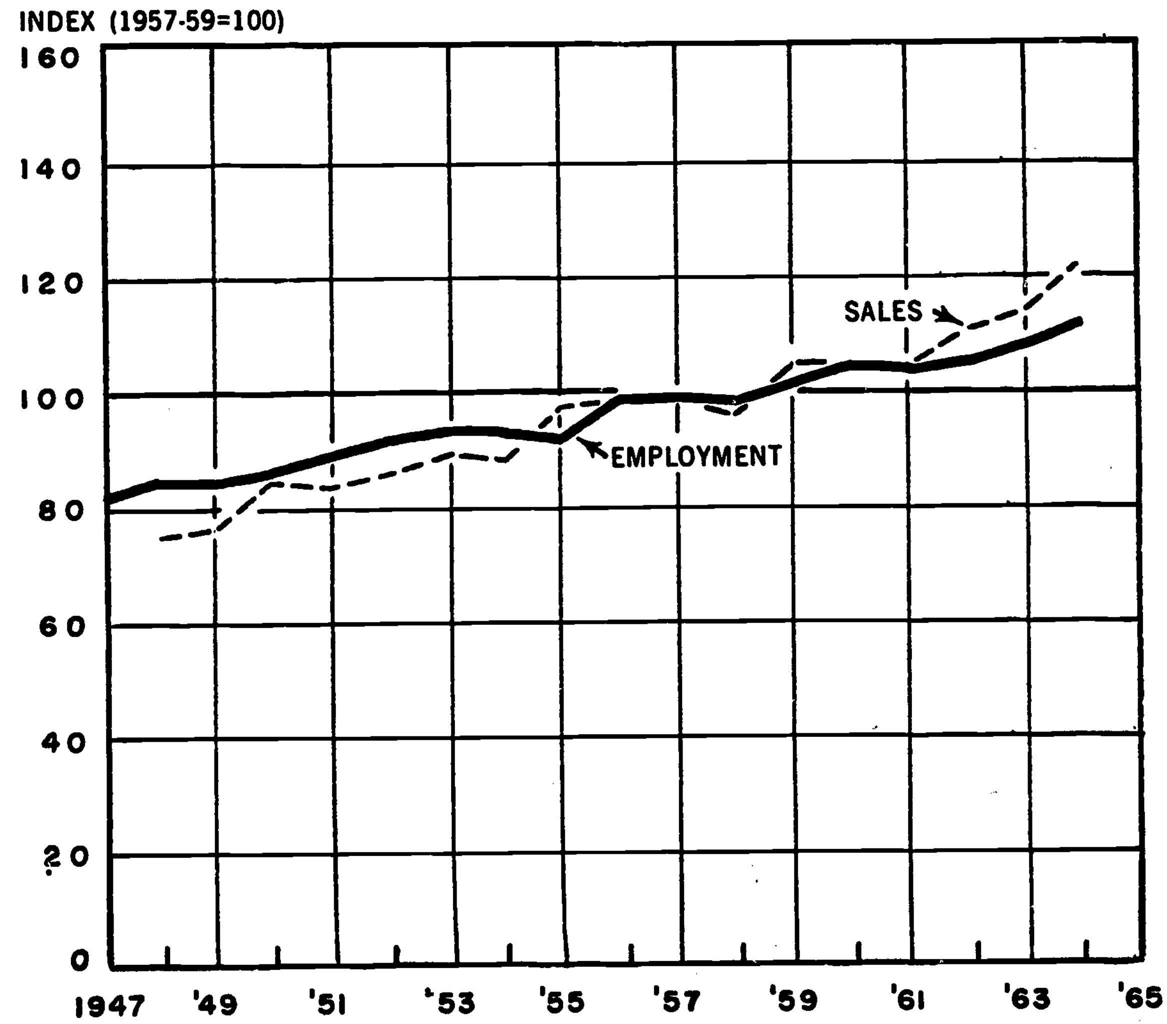
Employment requirements in wholesale and retail trade are expected to increase rapidly through the mid-1970's, because of increases in population and consumer expenditures. Labor requirements in retail trade are anticipated to rise slightly faster than in wholesale trade, continuing the trend of the past decade. Although total employment in wholesale and retail trade is projected to increase rapidly through 1975, technological innovations are expected to limit employment growth in some occupation groups.

Employment Trends

1947–64. Employment in wholesale and retail trade increased rapidly between 1947 and 1964, rising from nearly 9 million to about 12.1 million, or about 36 percent. During the 1954–64 decade employment in retail trade rose slightly faster than in wholesale trade. Retail trade workers increased

EMPLOYMENT AND SALES[1] IN WHOLESALE AND RETAIL TRADE, 1947-64

Employment (in 000's)	
1947	8,955
1948	9,272
1949	9,264
1950	9,386
1951	9,742
1952	10,004
1953	10,247
1954	10,235
1955	10,535
1956	10,858
1957	10,886
1958	10,750
1959	11,127
1960	11,391
1961	11,337
1962	11,566
1963	11,778
1964	12,132



Source: Employment, Bureau of Labor Statistics; sales estimated from Office of Business Economics' data.

[1] Includes all retail sales and sales of merchant wholesalers, but excludes wholesale sales by manufacturers' sales branches and sales offices, petroleum bulk plants and terminals, merchandise agents and brokers, and assemblers of farm products. Based on 1963 Census of Business data, sales of manufacturers' sales branches, etc., make up about 56% of total wholesale sales. Real value of sales estimated using wholesale and consumer price indexes.

from about 7.5 million to nearly 9 million, or an annual growth rate of about 1.8 percent, while employment in wholesale trade rose from approximately 2.7 million to 3.2 million, or about 1.6 percent per annum. In 1964, retail trade accounted for nearly three-fourths of total trade employment.

During the past decade, employment growth in both retail and wholesale trade establishments was limited by the increasing use of laborsaving technological innovations. Employment in wholesale trade was more affected because a larger proportion of the workers in this field were engaged in material handling, warehousing, and billing and other recordkeeping operations—activities that were particularly vulnerable to mechanization.

Employment growth in retail and wholesale trade during the post-World War II period resulted from growing population and rising per capita personal consumption expenditures. Between 1947 and 1964, population increased by about 33 percent and per capita personal consumption expenditures (in 1964 dollars) by 34 percent.

1964–75. Employment requirements in wholesale and retail trade are expected to increase from about 12.1 million in 1964 to about 16 million in 1975, an annual growth rate of about 2.5 percent compared with 1.8 percent between 1947 and 1964. Retail trade employment is anticipated to continue to rise slightly faster than employment in wholesale trade. Labor requirements in retail trade are projected to rise from nearly 9 million in 1964 to about 12 million in 1975, an annual rate of increase of about 2.7 percent, and requirements in wholesale trade are expected to increase from about 3.2 million in 1964 to about 4 million in 1975, an annual growth rate of 2 percent.

Retail and wholesale trade activity is expected to continue to increase rapidly through the mid-1970's mainly because of increasing population and consumer expenditures, and continuation of the movement of people from rural to urban areas and from cities to suburbs and the trend toward keeping stores open during evening hours. However, growth in employment requirements is expected to be slowed somewhat by the increasing application of laborsaving technology. A large part of the employment growth in trade establishments is expected to be among part-time workers, particularly women and young workers.

Effects of Technological Developments on Future Employment

Employment growth in this field is expected to be slowed by increasing the efficiency of retailing and wholesaling operations through improvements in materials handling methods, packaging innovations, the growing use of computers for inventory control and billing operations, the increasing use of automatic equipment in supermarkets, and growth in the number of self-service stores and departments of large stores.

The requirements for warehouse workers in both wholesale and retail establishments should be adversely affected by the increasing use of automatically controlled conveyors for sorting and moving goods into storage and selecting fast-moving items for shipment. A growing number of these systems will be controlled by computers. The efficiency of warehousing operations, particularly in wholesaling establishments, also is expected to be increased by the greater use of improved palletizing methods and packaging of items in normal purchase quantities (instead of by the dozen, gross, etc.), which should reduce materials handling.

The use of electronic data processing equipment in trade industries can be expected to accelerate in future years. For example, a probable development is the linking of data-processing equipment with communications systems to facilitate control over customer accounts, sales and inventory data, and other operating information from central locations of large multiunit trade organizations. The use of point-of-sale data recorders, such as punch sales tickets and cash register tapes designed for direct computer input also are expected to increase. The increasing use of electronic data processing systems to reduce routine clerical operations is expected to limit growth in the requirements for bookkeepers, accounting and inventory clerks, and billing and calculating machine operators. Although the need for persons skilled in operating electronic computers and peripheral equipment should increase, growth in employment of such workers in trade may be limited as some small retail and wholesale establishments are expected to contract out their recordkeeping work to computer service organizations.

In food supermarkets and other self-service retail establishments, growth in the requirements for workers such as markers and meat packagers is expected to be reduced by the increasing use of automatic wrapping and marking equipment, and miscellaneous powered devices that are used to prepare goods for merchandising. Still in the development stage are automatic checkout counters that total prices and bag items mechanically. These systems may be in prototype state by 1970 and their widespread use in the future could have a major impact on requirements for checkers and baggers.

The anticipated rapid growth of automatic (vending machine) merchandising of goods and services also is expected to limit growth in labor requirements for waiters, waitresses, and sales workers. However, the adverse effects of automatic merchandising will be at least partially offset by increasing requirements for workers to stock, service, and maintain vending machines. Several factors are expected to stimulate automatic merchandising in the years ahead. For example, improvements in currency-changing devices will make it possible to vend a greater variety of merchandise. Large machines that vend several hundred different items have recently been developed and are expected to be in general use by the mid-1970's. Also, research is underway to develop vending machines that will accept credit cards rather than coins or currency.

Finance, Insurance, and Real Estate (SIC Division G)

Summary

Employment requirements in finance, insurance, and real estate establishments are expected to increase approximately one-fourth between 1964 and 1975. Employment growth will be slower than in the past decade or so, primarily because of the increasing use of electronic data processing equipment.

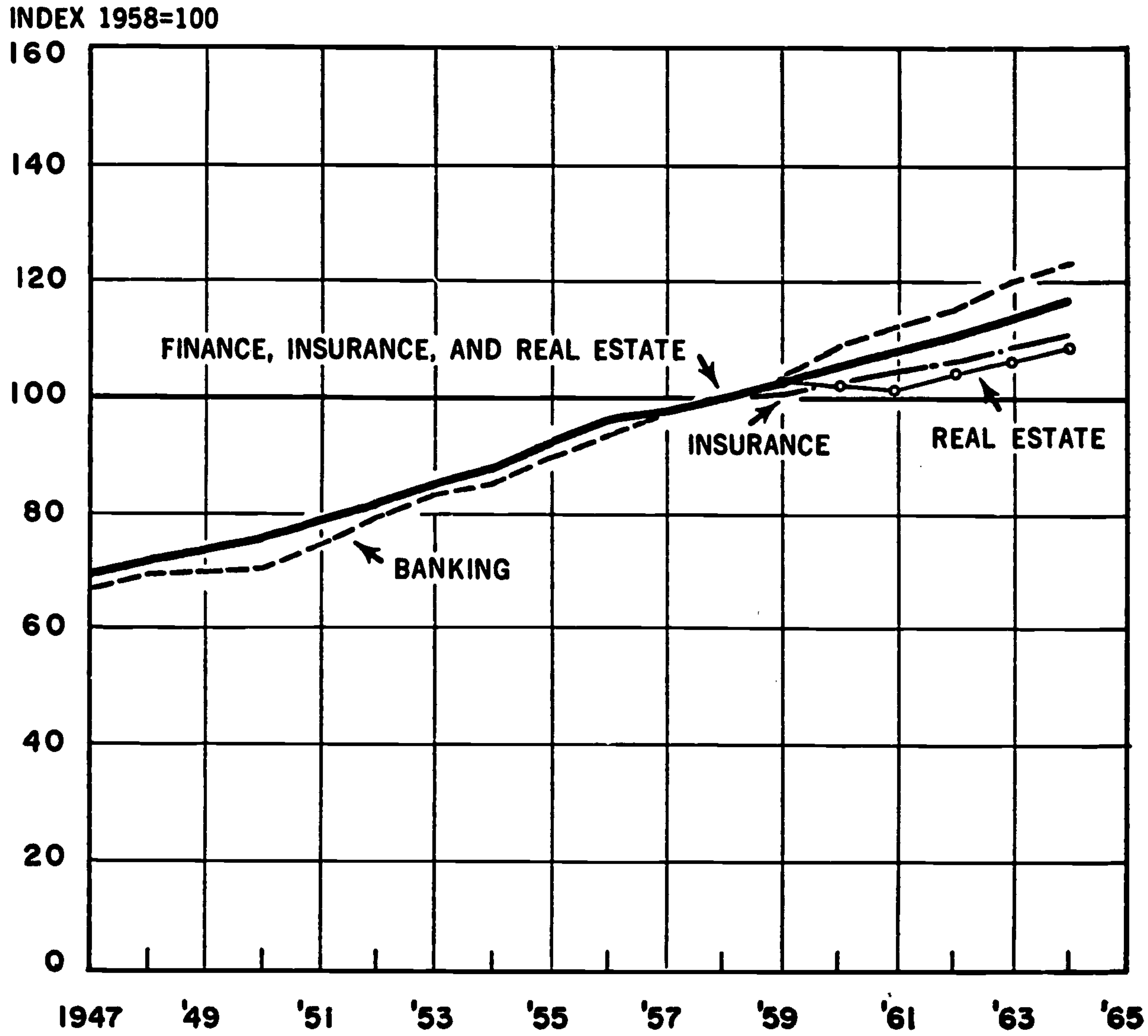
Employment Trends

1947–64. Employment in finance, insurance, and real estate establishments increased from nearly 1.8 million in 1947 to almost 3.0 million in 1964, a rate of growth more than twice that of total nonagricultural employment.

Four major industry groups—insurance carriers; insurance agents, brokers, and service; banking; and real estate—employed more than 80 percent of all employees in finance, insurance, and real estate establishments in 1964. Insurance accounted for more than one-third of the division's workers; banking, just over one-fourth; and real estate, nearly one-fifth. Most of the remaining workers were employed in two major industry groups—credit agencies other than banks and se-

EMPLOYMENT IN FINANCE, INSURANCE, AND REAL ESTATE, 1947-64

Employment (in 000's)	
1947	1,754
1948	1,829
1949	1,857
1950	1,919
1951	1,991
1952	2,069
1953	2,146
1954	2,234
1955	2,335
1956	2,429
1957	2,477
1958	2,519
1959	2,594
1960	2,669
1961	2,731
1962	2,800
1963	2,877
1964	2,964



Source: Bureau of Labor Statistics.

curity and commodity brokers, dealers, exchanges, and services—and a few were employed in other finance, insurance, and real estate establishments.

Between 1958 and 1964,[37] employment in finance, insurance, and real estate establishments rose about 17 percent; however, the rates of growth varied widely among the major industry groups. Employment increased by more than 35 percent in two major industry groups—credit agencies other than banks, and securities and commodity brokers, dealers, exchanges, and services. Employment rose by more than one-fifth in both the banking industry and the insurance agents, brokers, and insurance services industry. Although banking experienced the largest absolute rise in employment, its rate of increase was slowed by the expanding application of computers and related equipment to recordkeeping operations.

Employment in each of the three remaining major industry groups—insurance carriers; real estate; and other finance, insurance, and real estate establishments—rose by less than one-tenth. Among these groups, only the employment growth of insurance carriers was significantly affected by the computerization of clerical operations.

Finance, insurance, and real estate activities have expanded markedly with the postwar industrial and population growth. Between 1950 and 1963, for example, the amount of life insurance in force increased from \$234 billion to \$731 billion, while the value of property and casualty insurance premiums written rose from \$6.9 billion to about \$17 billion.[38] In approximately the same period, the number of checking accounts of commercial banks rose about 40 percent and the dollar value of their loans more than tripled.[39] Since World War II, significant increases also occurred in the volume of consumer credit outstanding and in the annual market value of securities sold. Assets of savings and loan associations increased and, with the expansion of homebuilding, these additional funds found ready loan outlets. The increased volume of homebuilding and other construction activities also led to an increase in the number and size of real estate firms.

1964–75. Employment requirements in finance, insurance, and real estate are expected to increase by about one-fourth between 1964 and 1975, to about 3.7 million. The expected annual rate of increase (about 2.1 percent) is nearly two-thirds that for the 1947–64 period.

Population growth and rising per capita income and levels of economic activity—factors largely responsible for the growth of employment in this division during the postwar period—are expected to stimulate future employment growth. As in the past, employment growth will be limited by the increasing application of laborsaving technological innovations. However, these innovations will not have equally adverse affects on employment. In banking, technological change is expected to be a significant factor in limiting growth in employment requirements, although not to the extent that it has in recent years. In insurance establishments, where operations also are heavily automated at present, employment growth is expected to be more adversely affected than in the past, as automation spreads into new areas. Employment growth in the remaining major industry groups, which have experienced relatively little mechanization of their operations, also will be limited by the increasing application of computers and related equipment.

Effects of Technological Developments on Future Employment

Technological advances, particularly in the application of computers, have allowed many establishments in these industries to process a rapidly increasing volume of paperwork. The banking and insurance industries were among the first to adopt the computer to large-scale clerical operations. The increasing use of computers has slowed employment growth in these industries in recent years, particularly of clerical workers.

In the future, computers will be applied to additional management oriented functions and to a greater range of customer services and conveniences. These new applications should in turn continue to adversely affect requirements for clerical workers, but create a need for increased numbers of management and professional employees to supervise and operate both the new services and the increased amount of automated equipment necessary to provide them. (More detailed discussion of technological changes in banking, insurance, and real estate are included in the following individual statements.)

[37] BLS employment (payroll) data for most finance, insurance, and real estate industry groups are not available for the years prior to 1958.

[38] *Insurance Yearbook,* Life Volume, the Spectator, Philadelphia, Pa., and *Life Insurance Fact Book,* Institute of Life Insurance, New York, N.Y. (*Statistical Abstract of the United States, 1964,* U.S. Department of Commerce, table 640, p. 475) and, Best's Fire and Casualty News, November 1963, pp. 22 and 23.

[39] *Monthly Labor Review,* September 1962, table 2, p. 991; *Business Statistics,* 1963 edition, U.S. Department of Commerce, pp. 89–91; and *Federal Reserve Bulletin,* March 1965, Board of Governors of the Federal Reserve System, pp. 447 and 472.

Banking (SIC 60)

Summary

Employment requirements in banking are expected to rise rapidly through the mid-1970's because of increasing population, personal and corporate income, use of credit, popularity of checking accounts, and number of services offered by banks. Laborsaving innovations are expected to be significant in banking through the mid-1970's, although not to the extent that they have been in recent years.

Employment Trends

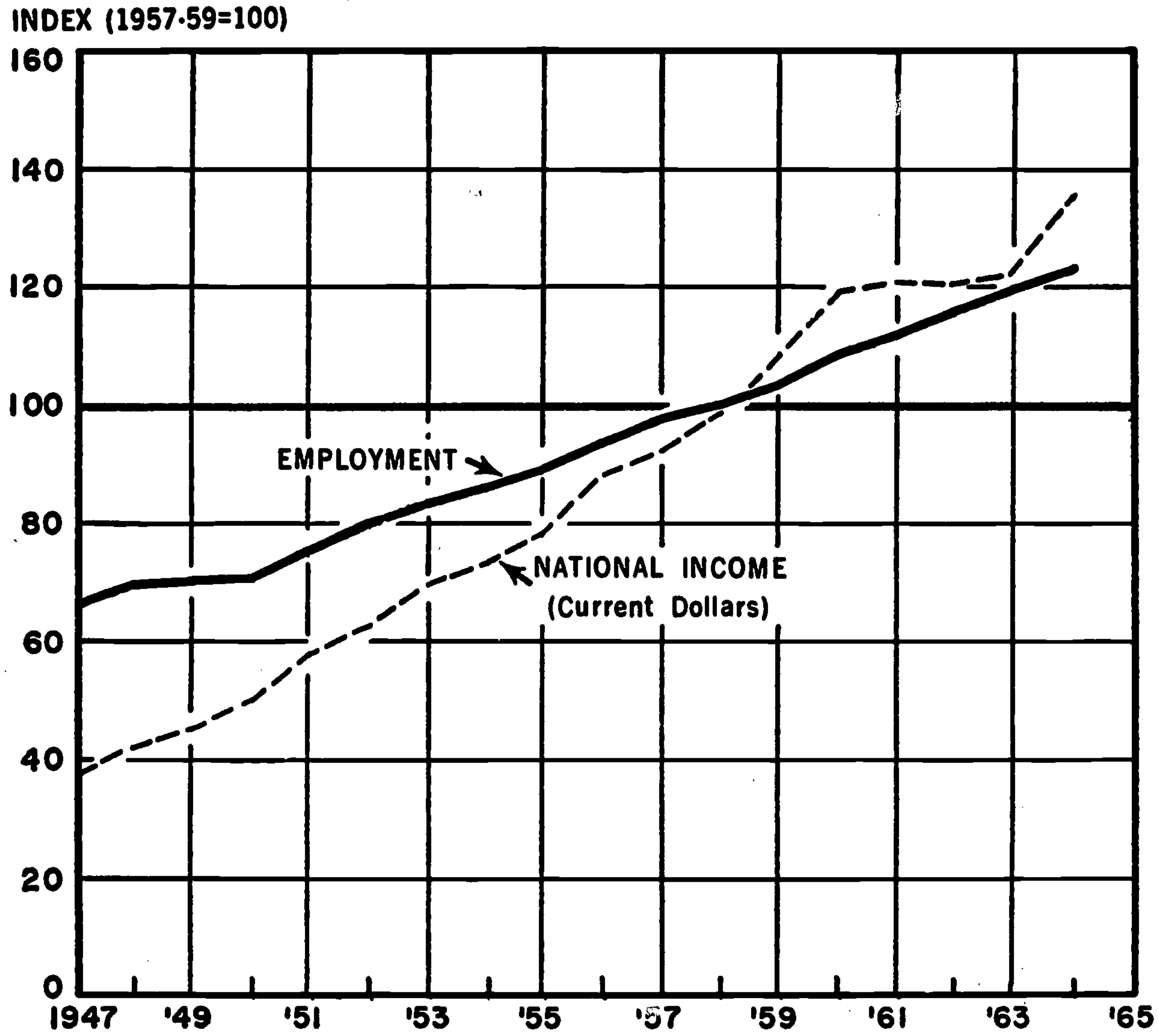
1947–64. Employment in banking rose from 411,000 in 1947 to 764,000 in 1964, an increase of 86 percent, despite increasing automation of banking operations.[40]

During the post-World War II period, banking activity rose sharply, primarily because of rising population and personal and corporate income. Between 1949 and 1960, checking accounts at commercial banks rose by about 40 percent and the average number of checks per account cleared annually through the Federal Reserve System increased by almost 32 percent. Between 1951 and 1964, the total number of checks handled annually by the Federal Reserve System more than doubled. Banks also introduced many new services and expanded old ones. They started accepting payment for utility bills, reconciling business checking accounts, and expanding branch-office facilities. The widespread introduction of checking accounts

[40] For a more complete discussion of trends and outlook in banking, see "Changing Manpower Requirements in Banking," *Monthly Labor Review*, September 1962, pp. 989–996.

EMPLOYMENT AND NATIONAL INCOME ORIGINATING IN BANKING, 1947-64

Employment (in 000's)	
1947	411
1948	429
1949	432
1950	435
1951	461
1952	490
1953	514
1954	529
1955	549
1956	579
1957	603
1958	617
1959	641
1960	673
1961	694
1962	715
1963	741
1964	764



Source: Employment, Bureau of Labor Statistics; national income, Office of Business Economics.

requiring no minimum balance further contributed to increased banking activity. Recent changes in banking regulations now allow commercial banks to offer interest rates on savings accounts that are competitive with those of other types of financial institutions, such as savings and loan associations. Banks also have increased their consumer business and real estate credit activities. The dollar value of consumer installment loans increased four times between 1950 and 1964, while the dollar value of all loans made by commercial banks more than tripled.

1964–75. Employment requirements in banking are expected to increase from about 764,000 in 1964 to 1.1 million in 1975, an annual rate of 3.3 percent compared with 3.7 percent between 1947 and 1964.

Many of the trends responsible for the rapid increase in banking activities and employment in the postwar years are expected to continue through the mid-1970's. These trends include increasing population, rising levels of income, growing use of credit, and increasing popularity of personal checking accounts. As income levels rise, many of the families without bonds, stocks, or bank savings (currently more than one-third of all families) will likely start such savings.

Employment requirements in banking are not expected to increase as fast as banking activity because of the greater use of computers and other laborsaving innovations. For example, although electronic data processing (EDP) equipment is already used extensively in many banks, its use is expected to expand significantly as it is used in a growing number of banks and applied to additional banking functions.

Effects of Technological Developments on Future Employment

Technological change is expected to be a significant factor affecting employment requirements in banking through the mid-1970's. The major impact of technology will be on employment of clerical workers, where the more widespread use of electronic computers and other technological innovations are expected to reduce unit labor requirements.

The application of computers to banking operations has increased rapidly in recent years and a continued rise in the number of banks that use computers is anticipated. Between 1962 and 1965, there was an increase of more than 125 percent in the number of banks that operated their own computers, contracted for computer services either with correspondent banks or with independent computer service bureaus, or shared computer time with another organization. According to a 1964 American Bankers Association survey, computer services are expected to be used by all banks with deposits of $100 million or more during the 1970–75 period, by 90 percent of those with $50–$99 million in deposits, and by more than two-thirds of those with deposits in the $10–$49 million range.[41]

EDP equipment has been applied to such banking functions as the processing of checks, loans, and savings accounts. In the years ahead, EDP is expected to be extended to additional functions, including consumer credit, check account reconciliation, and customer payroll activities, which should add to the volume of banking business with little increase in requirements for clerical workers. For example, EDP is being used in connection with touch-tone card dialers, a development that may eventually curtail the use of checks in financial transactions. Already being tested are direct card dialing connections between local retailers and bank computers.

The use of checks coded with Magnetic Ink Character Recognition (MICR) numerals should permit banks to handle a substantially greater number of checks without a corresponding increase in the need for bookkeepers and other clerical workers. MICR, already used on more than 90 percent of all checks cleared through the Federal Reserve System, involves the printing of special characters on checks, which, in turn, permits rapid machine sorting through mechanical reading of the characters. MICR also enables direct transfer of information from checks to computers.

Improvements in data transmission systems may make possible the transmission of facsimile checks between banks cheaper than shipping the actual checks. The widespread use of this system could virtually eliminate interbank transfer of checks and significantly reduce the need for clerical workers to tabulate and sort checks.

The efficiency of banking operations also is expected to increase through the increasing use of recent innovations such as electronic bookkeeping machines, machines to receive and receipt deposits, and closed circuit TV combined with pneumatic tubes (facilitating drive-in service).

Although the automation of banking operations is expected to adversely affect requirements for workers in some occupations, it should increase requirements in others. For example, the growing use of computers should boost requirements for workers skilled in the operation of computers, including the peripheral equipment used with them. Because of the expected increase in banking activity and the number of services offered by banks, requirements for bank officers in areas requiring personal attention, such as credit, trusts, and investment, also should grow. The number of bank tellers also is expected to increase substantially, despite the introduction of equipment that will enable them to perform their work more rapidly.

[41] "Banking Automation—1975," *Banking*, July 1964, p. 46.

Insurance (SIC 63 and 64)

Summary

Employment requirements in insurance are expected to increase moderately between 1964 and 1975. A substantial increase is anticipated in insurance activity, because of increasing population in the prime insurance-purchasing age groups, rising personal income, greater awareness of the financial needs for retirement, and an expanding stock of insurable goods. Technological change is expected to be a significant factor in limiting employment growth in insurance through the mid-1970's.

Employment Trends

1958–64. Insurance employment rose rapidly during the post-World War II period. Between 1958 [42] and 1964, employment rose from about 1 million to more than 1.1 million.

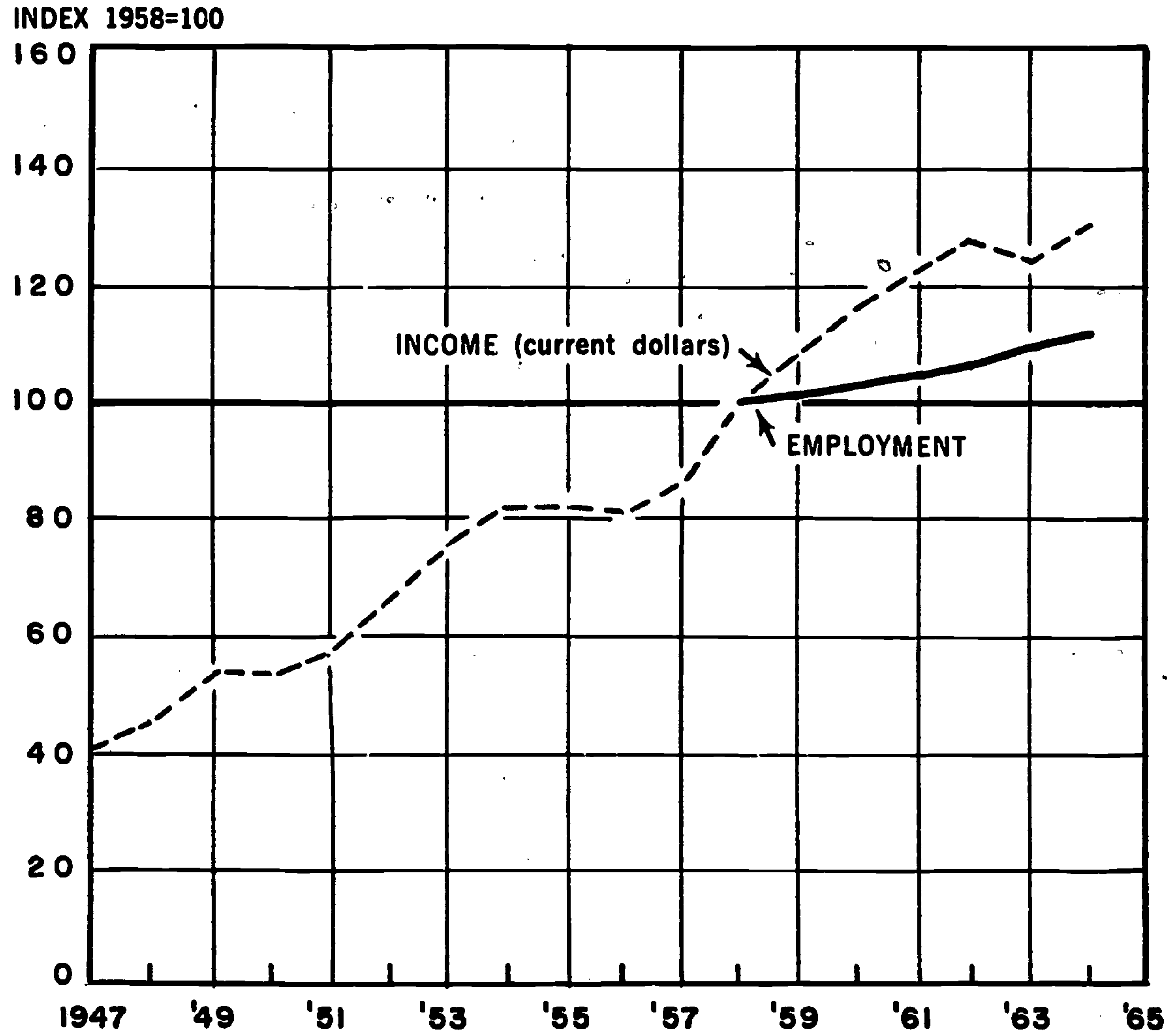
Between 1958 and 1964, employment grew faster in insurance agents, brokers, and services establishments than in insurance carrier establishments. However, insurance carriers accounted for nearly three-fifths of the increase in employment during this period and for about 80 percent of insurance employment in 1964. Employment growth in insurance carriers was limited by the application of technological innovations that reduced the need for clerical personnel.

Insurance sales and employment rose during the post-World War II period mainly because of rising population in the 15 to 44 age group (which

[42] BLS employment (payroll) data for the insurance major industry groups are not available for years prior to 1958.

EMPLOYMENT AND NATIONAL INCOME ORIGINATING IN INSURANCE, 1947-64

Employment (in 000's)	
1958	999
1959	1,007
1960	1,028
1961	1,048
1962	1,064
1963	1,091
1964	1,121



Sources: Employment, Bureau of Labor Statistics; national income, Office of Business Economics.

accounts for most insurance sales), rising personal income, and longer life expectancy. The number of people in this age group rose from about 67 million in 1950 to just over 75 million in 1963.[43] These individuals buy large amounts of life insurance because of their family responsibilities. For example, in 1963, this group accounted for 82 percent of the total dollar amount of ordinary life insurance purchased.[44]

Higher levels of personal income enabled people to purchase increasing amounts of insurance and to make more numerous and expensive purchases of such items as automobiles. Insurance on such purchases provides the major source of income for property and casualty companies. Between 1958 and 1962, expenditures on insurance premiums rose from just under $28 billion, to an estimated $38 billion,[45] an increase of about 36 percent. This increase in premium expenditures was in turn reflected in a higher value per insurance policy. For example, in 1963, the average new ordinary life policy was $7,100, while the average value per policy for all ordinary life insurance in force was only $4,100.[46]

Another boost to insurance sales occurred as the rising standard of living and advances in medical science enabled people to look forward to a longer life expectancy than in the past, and increased their interest in life insurance as a means for building adequate retirement funds. Insurance sales also were stimulated by the growing importance of group life, health, and accident policies.

1964–75. By 1975, employment in this industry may reach 1.25 million, approximately 11 percent higher than the 1.1 million employed in 1964. The average annual rate of growth implied by the projection—about 1 percent—is much slower than the 2 percent experienced in the 1958–64 period. This slowdown in the rate of growth is anticipated because of the increasing automation of insurance operations.

Among the factors expected to have a positive effect on insurance employment in the 1965–75 decade are increasing population in the prime insurance purchasing age groups (the number in the 15- to 44-year group will increase from 75 million in 1963 to 93 million in 1975); rising personal income; greater awareness of the financial needs for retirement; and an expanding stock of insurable goods, such as homes, boats, and automobiles. If the practice of self-insurance by large corporations continues to grow, employment growth in the industry may be dampened. The self-insurance system bypasses the insurance company because, under this system, business firms set up and service their own group insurance programs.

Insurance employment is not expected to rise as fast as insurance activity. One important reason is the increasing computerization of insurance operations, which is expected to adversely affect the need for clerical workers. In addition, employment growth in clerical and sales occupations may be reduced somewhat by the increasing importance of policies that combine several types of coverage. All-line policy selling and group insurance enable a salesman to handle larger volumes of insurance sales than otherwise possible and significantly reduces recordkeeping.

Effects of Technological Developments on Future Employment

Increasing use of data processing and data transmission equipment for home office clerical operations is expected to have an adverse effect on insurance employment growth. The number of routine clerical jobs will probably be reduced significantly. On the other hand, requirements may increase for personnel skilled in the operation of computers and peripheral equipment.

Data transmission systems already are being used to send information from field offices to home office computer centers, or to link district computer centers. The expanded use of such equipment is expected to reduce growth in the number of field office employees engaged in recordkeeping functions without comparable increases in requirements for home office personnel. Various reading and sensing techniques are being introduced in areas such as premium collection. For example, check-writing and handling operations are being coordinated with magnetic ink character recognition systems similar to those used by banks. These developments are designed to reduce the amount of input preparation done by workers such as keypunch operators.

In addition to improvements in data processing techniques, insurance employment also will be affected by changes in marketing methods and industry organization. For example, direct selling (using mail, advertising, and company agents) is increasing, particularly in the case of automobile lines. Carrier consolidation has been encouraged by changes in State regulatory laws that now allow fire and casualty companies to write all types of nonlife lines. Consolidated insurance companies can service several lines of insurance, with some reduction in unit labor requirements.

[43] *U.S. Census of Population*, 1960, Vol. 1, U.S. Department of Commerce, table 158, pp. 1–360; and *Current Population Reports*, Series P–25, No. 276, November 19, 1963, U.S. Department of Commerce, table 1, p. 11.
[44] *Life Insurance Fact Book*, 1964, Institute of Life Insurance, p. 20.
[45] Institute of Life Insurance, February 1963.
[46] Ibid., December 1965.

Real Estate (SIC 65)

Summary

Employment requirements in real estate are expected to increase moderately between 1964 and 1975. Technological change is not expected to affect employment growth significantly through the mid-1970's, because of the small size of the average real estate firm and because the business is service oriented.

Employment Trends

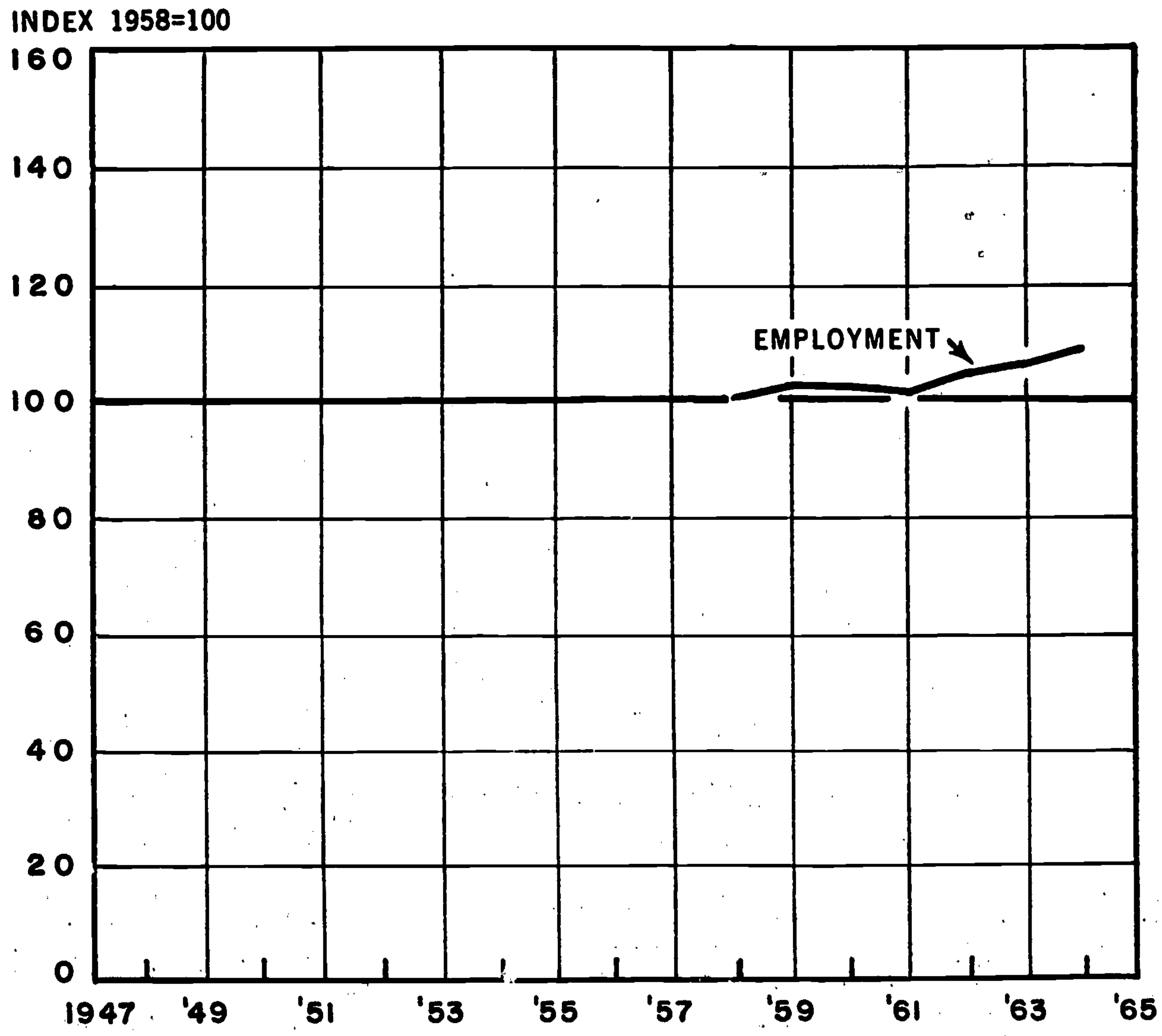
1958–64. Employment in the real estate major industry group increased from 507,000 in 1958 to 558,000 in 1964.[47] This employment growth resulted primarily from rising building activity, particularly for residential housing and commercial structures; the shift of families from cities to the suburbs and from rural to urban areas; rising personal income; and favorable credit terms resulting mainly from Government legislation, for example, Veterans' Administration (VA) and Federal Housing Administration (FHA) home-loan guarantees.

In 1964, operative builders (firms that are engaged primarily in construction for sale on their own account) and subdividers and developers accounted for slightly less than 20 percent of total employment in this major industry group. However, these two types of enterprises accounted for the majority of the group's actual employment growth in recent years. The largest concentration of employment in other real estate activities was in the operators and lessors industry group, which includes real estate operators (except developers) of nonresidential and apartment developments, and lessors of real property, such as agricultural and forest. On the basis of indirect evidence, em-

[47] BLS employment (payroll) data for the real estate major industry group are not available for the years prior to 1958.

EMPLOYMENT IN REAL ESTATE, 1958-64

Employment (in 000's)	
1958	507
1959	520
1960	517
1961	514
1962	530
1963	543
1964	558



Source: Bureau of Labor Statistics

ployment in this industry group has changed little in recent years. On the other hand, the agents, brokers, and managers industry has experienced employment growth and has accounted for about 20 percent of total real estate employment since 1958.

Increased building, including urban renewal activities, has resulted in increasing employment in the subdividers and developers industry. Establishments in this industry are engaged in subdividing property into lots and developing them for resale by others or for their own account.

Employment grew in the agents, brokers, and manager industry, as rising population increased the demand for housing and as high-mobility rates resulted in frequent buying and selling of homes. Between 1947 and 1963, the number of people changing their place of residence annually increased from about 28 million to more than 35 million.[48] Some major factors causing people to move were shifts in population from rural to urban and from city to surburban locations; the increasing percentage of younger people, who tend to move more frequently than older age groups; the tendency to trade-up to better housing as income increased; and the increase in the size of families, which stimulated demand for larger living quarters.

Rising levels of personal income coupled with favorable credit terms served to encourage construction activity and enabled a larger proportion of people to own their own home. The number of owner-occupied farm and nonfarm dwelling units rose from about 20 million in November 1945, to about 32.8 million in April 1960.[49] Housing expenditures have accounted for an increasingly larger share of all consumer expenditures in recent years, rising from 12.2 percent in 1955 to 12.8 percent in 1960.[50] Expenditures on owner-occupied housing rose from 7.4 percent to 8.1 percent of consumer expenditures in the same period.[51] Government legislation to guarantee home loans through the VA and FHA were significant developments in the area of home credit. Competition among financial institutions for real estate loans also served to make private housing credit more readily available.

Rising industrial production spurred the need for industrial and commercial buildings during the post-World War II period. Between 1947 and 1964, the number of new businesses incorporated annually rose from about 112,000 to just under 200,000.[52] Between 1951 and 1964, the net sales and profits of manufacturing corporations with assets of $1 million and over increased approximately 90 percent.[53] Along with the expansion of business, increases in white-collar employment forced many businesses to expand their office space and created a strong demand for construction of new office buildings. The construction of other types of commercial stuctures such as hotels, motels, and shopping centers also increased in recent years.

1964–75. Manpower requirements in the real estate major industry group are expected to increase moderately in the years ahead. By 1975, employment needs may reach 650,000, or 17 percent above the 1964 level. Employment will be stimulated by the same factors as during the postwar period.

Employment requirements of operative builders and subdividers and developers should continue to increase with the demand for housing, and the greater emphasis on urban renewal activities. Employment of agents, brokers, and managers should expand as population and personal income increase, and as population mobility remains at a high level.

The demand for housing will be strong during the first half of the 1970's, stimulated by such demographic factors as a rapid increase in new family formations. The market for office and other commercial structures and for apartment houses is also expected to remain strong, stimulated primarily by factors, such as rising levels of business activity, urban renewal, and the increasing popularity of intown living.

Effects of Technological Developments on Future Employment

Technological changes are not expected to effect significantly employment growth in real estate through the mid-1970's, because of the small size of the average firm and because the business is service oriented. In 1962, more than four-fifths of all real estate establishments had fewer than four employees, and these firms accounted for about one-third of total employment.[54] In addition, the application of data processing has been limited by the employment of family members in clerical work by many of the smaller firms. In the future, however, the development of smaller and more flexible computers than are currently available, along with increased contracting of work to computer service bureaus, should stimulate the use of electronic data processing (EDP) equip-

[48] *Current Population Reports, Series P–20. No. 134,* Bureau of the Census, March 25, 1965, pp. 12 and 13.
[49] *Housing and Home Finance Agency, 1963 Annual Report,* table B–21, p. 452.
[50] *The Changing American Population,* a report of the 1961 Arden House Conference on the Changing American Population, jointly sponsored by the Graduate School of Business, Columbia University, and the Institute of Life Insurance, New York, 1962.
[51] Ibid.

[52] *Small Business Administration, 1964 Annual Report,* p. 6.
[53] Ibid., p. 11.
[54] *County Business Patterns, First Quarter 1962, Part I, U.S. Summary,* U.S. Department of Commerce, p. 18.

ment and increase the recordkeeping efficiency of the smaller firms.

An increasing number of the relatively few large firms in the industry, mainly real estate management firms, are expected to apply EDP equipment to company functions with a resultant drop in unit labor requirements for clerical workers. Many firms are already using EDP to send out rent bills, compile daily statements, and speed up other bookkeeping operations.

Although the increasing use of EDP equipment is expected to adversely affect requirements for clerical workers such as billing clerks and bookkeeping machine operators, it will increase employment requirements for workers skilled in the operation of computers and peripheral equipment.

Services (SIC Division H)

Summary

Employment requirements in the services division are expected to increase rapidly between 1964 and 1975. This increase will stem mainly from the rising demand for service functions by our growing, more affluent population. Technological change is not expected to limit employment growth significantly in this division through the mid-1970's, because of the personalized nature of most of the services performed.

Employment Trends

1947–64. Employment in this division increased rapidly from nearly 5.1 million in 1947 to about 8.6 million in 1964. Employment growth has resulted primarily from substantial increases in our population, a rapid rise in personal disposable income, and growing demand for services that add to people's comfort and enjoyment and protect lives and property.

In 1964, medical and other health services comprised one-fourth of total employment in this industry division; nonprofit membership organizations and miscellaneous business services accounted for 13 percent and 11 percent of employment, respectively. Other major industry groups with significant numbers of workers were hotels and other lodging places, personal services, automobile repair services, amusement and recreation services, educational services, private household services, and miscellaneous services. The remaining workers were employed in miscellaneous repair services; motion pictures; legal services; and museums, art galleries, botanical and zoological gardens.

Between March 1959 and March 1964,[55] employment increased in all but one of the major industry groups in the service division. Miscellaneous business services, the fastest growing industry, increased close to one-half over the period, as higher levels of business activity occasioned increased expenditures by business firms on such services as management consulting, research and development work, consumer-credit reporting, building maintenance, and advertising. In medical and other health services, employment increased by about one-third, primarily because of expanding population with its increasing proportion of very young and very old people—the groups most needing medical care; and from the increasing amount of money being spent on health and medical programs. Employment in automobile repair and legal services expanded by roughly one-quarter, and amusement and recreation services, educational services, museums and art gallaries, and miscellaneous repair and other services each grew by close to one-fifth, reflecting the increasing demand for varying types of service by our rising, more affluent population. Personal services and nonprofit membership organizations showed the slowest rate of employment growth, both increasing by about 7 percent over the period. Motion picture employment decreased by about 10 percent, in part, because more films were being made on location in other countries.

1964–75. Between 1964 and 1975, manpower requirements in this division are expected to rise by more than two-fifths, to about 12.3 million.

Factors that will contribute to the rapid increase in services employment requirements in the years ahead include continuing population increases, expanding interest in preventive medicine and rehabilitation of the handicapped; the increased need to protect life and property as urbanization continues and cities become more crowded; and the more frequent use of restaurants, beauty parlors, and other services by families and individuals as income levels and leisure-time rise and as an increasing number of housewives take jobs outside the home.

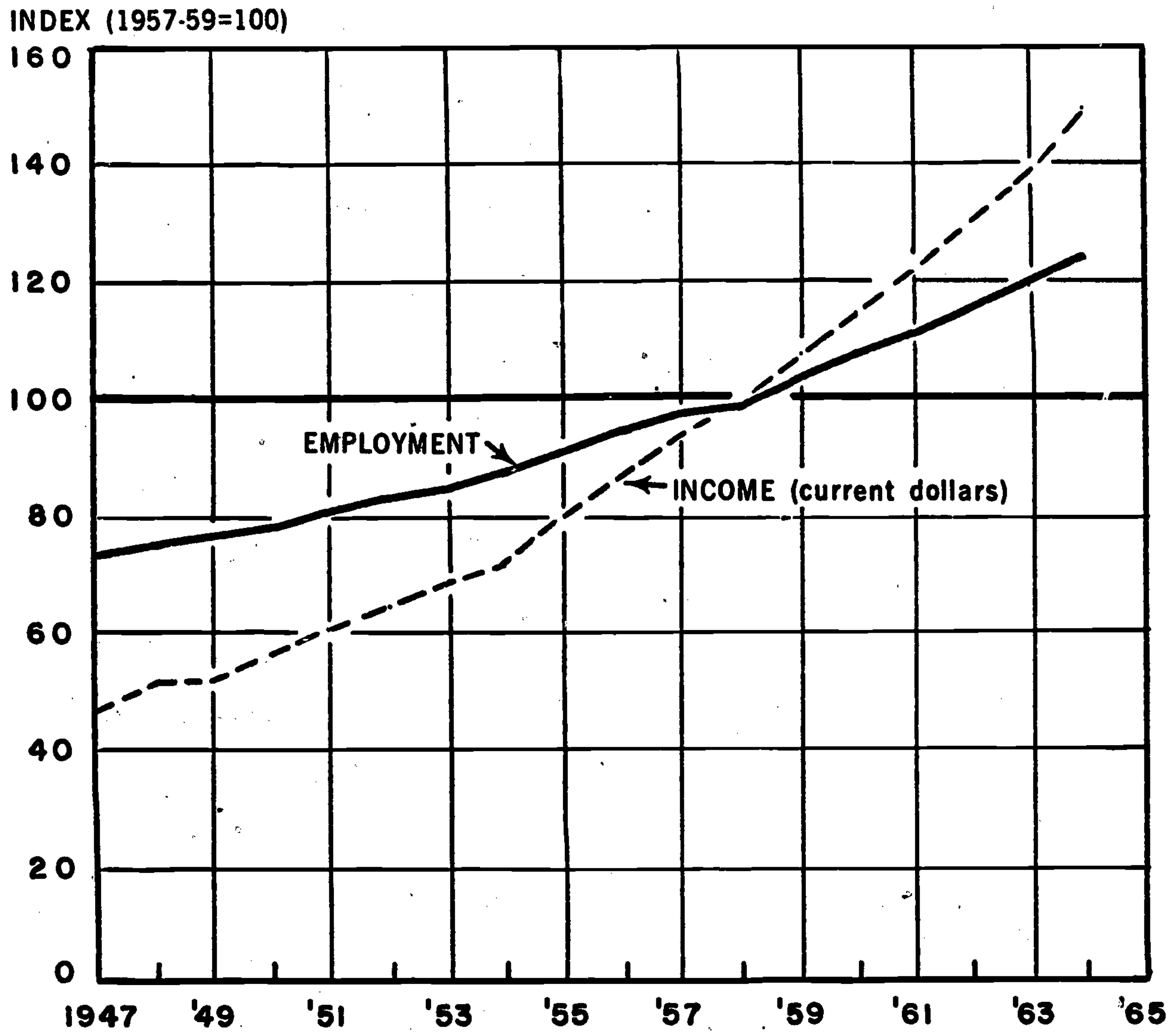
Requirements in educational services are expected to grow especially rapidly as more young people attend schools at all levels. Expanding Government assistance for vocational and adult education; and training and education for youth, the poverty stricken, and the unemployed, also will increase employment requirements in educational services.

Manpower requirements in business services of all kinds also are expected to grow as business firms rely increasingly on advertising services to sell their products; accounting, auditing, bookkeeping, and computing services to handle their fiscal recordkeeping; contract firms to provide maintenance services; audit bureaus and collecting agencies to cope with the increasing use of consumer credit; and research and development firms to provide and test new and improved products.

[55] BLS employment (payroll) data are not available for the major industry groups for the years prior to 1959 (benchmark data).

EMPLOYMENT AND NATIONAL INCOME ORIGINATING IN SERVICES, 1947-64

Employment (in 000's)	
1947	5,050
1948	5,206
1949	5,264
1950	5,382
1951	5,576
1952	5,730
1953	5,867
1954	6,002
1955	6,274
1956	6,536
1957	6,749
1958	6,811
1959	7,115
1960	7,392
1961	7,610
1962	7,947
1963	8,226
1964	8,569



Sources: Employment, Bureau of Labor Statistics; national income, Office of Business Economics.

Effects of Technological Developments on Future Employment

The necessity for extensive person-to-person contact in the performance of service functions limits the impact of technological innovations on employment requirements. Many of the establishments in this industry division are small and have limited investment potential, factors that will tend to slow the introduction of laborsaving technological innovations.

Clerical and kindred workers probably will be most affected by technological developments in the services division as automatic data processing equipment is used increasingly by smaller firms. Other new products and equipment also may affect employment requirements. For example, drip-dry textiles may reduce the need for laundry service workers, and home beauty products may limit the growth of beauty shop employment. However, the number of service workers expected to be eliminated will be far fewer than the number of new employees needed to meet the growing demand for services.

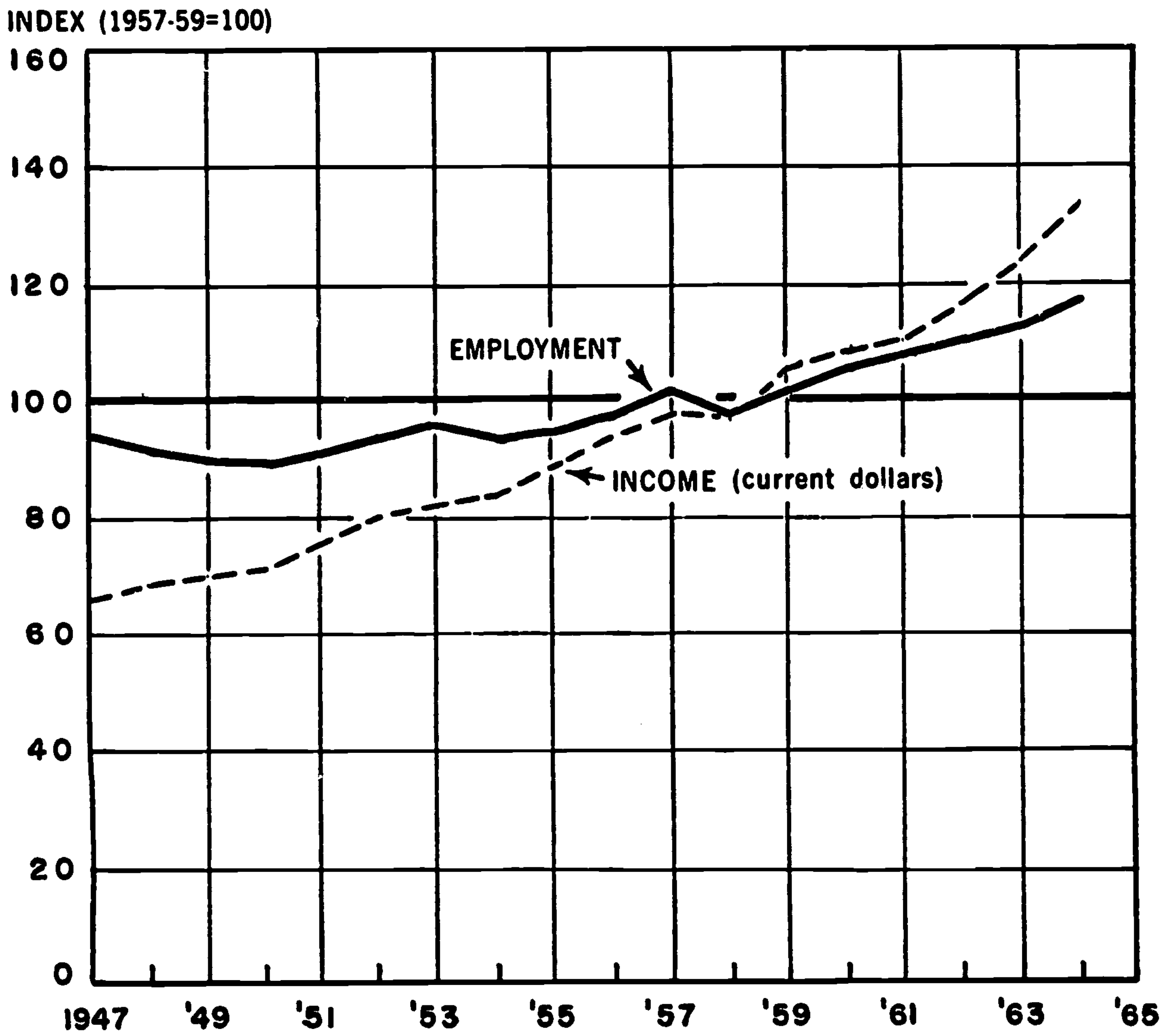
Hotels, Rooming Houses, Camps, and Other Lodging Places (SIC 70)

Summary

Employment requirements in hotels, rooming houses, camps, and other lodging places are expected to increase rapidly between 1964 and 1975. Employment requirements should grow mainly because of increases in population, business activity, income, and leisure time—factors that will

EMPLOYMENT AND NATIONAL INCOME ORIGINATING IN HOTELS, ROOMING HOUSES, CAMPS, AND OTHER LODGING PLACES, 1947-64

Employment (in 000's)	
1947	506
1948	495
1949	486
1950	481
1951	489
1952	503
1953	514
1954	504
1955	508
1956	525
1957	544
1958	527
1959	547
1960	565
1961	577
1962	595
1963	606
1964	640



Sources: Employment, Bureau of Labor Statistics; national income, Office of Business Economics

stimulate travel. Technological change is not expected to limit employment growth significantly in this major industry group through the mid-1970's, because of the personal nature of many of the services performed.

Employment Trends

1947–64. Employment in hotels, rooming houses, camps, and other lodging places increased by about one-quarter between 1947 and 1964, rising to approximately 640,000 in 1964.

In 1964, 90 percent of total employment in this major industry group was accounted for by hotels, motels, and tourist courts. The remaining employees worked in rooming and boarding houses; trailer parks and camps; and organization hotels and lodging places run on a membership basis.

Although the number of hotels decreased by about 8 percent between 1958 and 1963, this decline was offset by an increase of the same magnitude in the number of motels. These countervailing trends in the number of establishments were reflected similarly in employment: Hotel employment declined 10 percent and motel employment increased 27 percent over the same period.

1964–75. Manpower requirements in the major industry group are expected to rise rapidly between 1964 and 1975, to about 820,000. The anticipated employment growth will result partly from increasing travel associated with higher levels of business activity, expanding population, greater personal income, and more leisure time. In addition, employment expansion will be stimulated by the increasing variety and elaborateness of hotel services and accommodations, such as providing facilities and service for conferences, banquets, and social and civic entertainment needs; recreational facilities, such as tennis courts, swimming pools, exercise rooms, and boating; weekend entertainment programs; shuttle services, vacation packages for foreign and domestic travelers offered in conjunction with transportation companies; and "instant motels"—low cost mobile units that can be quickly placed in anticipation of a heavy influx of travelers. Some of the personnel required to implement these new and expanding hotel services will need special training in such areas as physical education, recreation, management, and the performing arts.

Effects of Technological Developments on Future Employment

So far, employment growth in this industry has not been significantly affected by the introduction of technological innovations. Nearly 6 of every 10 who work in this industry perform some kind of personal service that does not lend itself to mechanization—for example, the work of waiters and waitresses, and cooks and chefs. Another 2 of every 10 workers are managers, officials, and proprietors performing functions that may be aided, but not substituted for, by machines. The workers most affected by mechanical aids are clerical workers and kitchen helpers. For example, the use of electronic data processing equipment and other types of office machines is now widespread in this industry and is expected to increase further. The increasing use of automatic dishwashing equipment, vegetable cutters and peelers, and other mechanical kitchen equipment will continue to limit the growth in employment requirements for kitchen helpers. Also, the use of food, soft drink, sandwich and other vending machines has and will continue to affect adversely employment requirements for counter and fountain workers.

Miscellaneous Business Services (SIC 73)

Summary

Employment requirements in the miscellaneous business services major industry group are expected to increase very rapidly between 1964 and 1975. This increase will result from the steadily rising demand for services from a growing, more affluent population. Technological change is not expected to have a significant impact on employment growth through the mid-1970's.

Employment Trends

1959–64. Employment in this major industry group increased from 670,000 in March of 1959, to about 980,000 in March 1964,[56] an annual rate of increase of about 8 percent. In 1964, "other business services"[57] establishments employed about 60 percent of total employment in this major industry group; establishments furnishing services to dwellings and other buildings accounted for about 16 percent; and the remaining workers were in establishments rendering services in the areas of advertising; consumer credit and mercantile reporting, and adjustment and collection; and duplicating, addressing, blueprinting, photocopying, mailing, mailing list, and stenographic services.

Although employment in all major segments of miscellaneous business services has been increasing, "other business services" and "services to dwellings and other buildings" experienced the greatest employment growth over the 1959–64 period. Employment in the services to dwellings and other buildings establishments increased from 93,000 to 157,000, an increase of 69 percent; while other business services grew by 58 percent, from 373,000 to 591,000 employees. Employment in credit bureaus and collecting agencies also expanded fairly rapidly (28 percent) over the 1959–64 period, rising from 48,000 to 62,000. Employment growth in other segments of the miscellaneous business services group, however, was much less rapid. The number of workers employed in direct mail advertising, duplicating, mailing, copying, and stenographic services, and in advertising increased by only 10 percent and 8 percent, respectively.

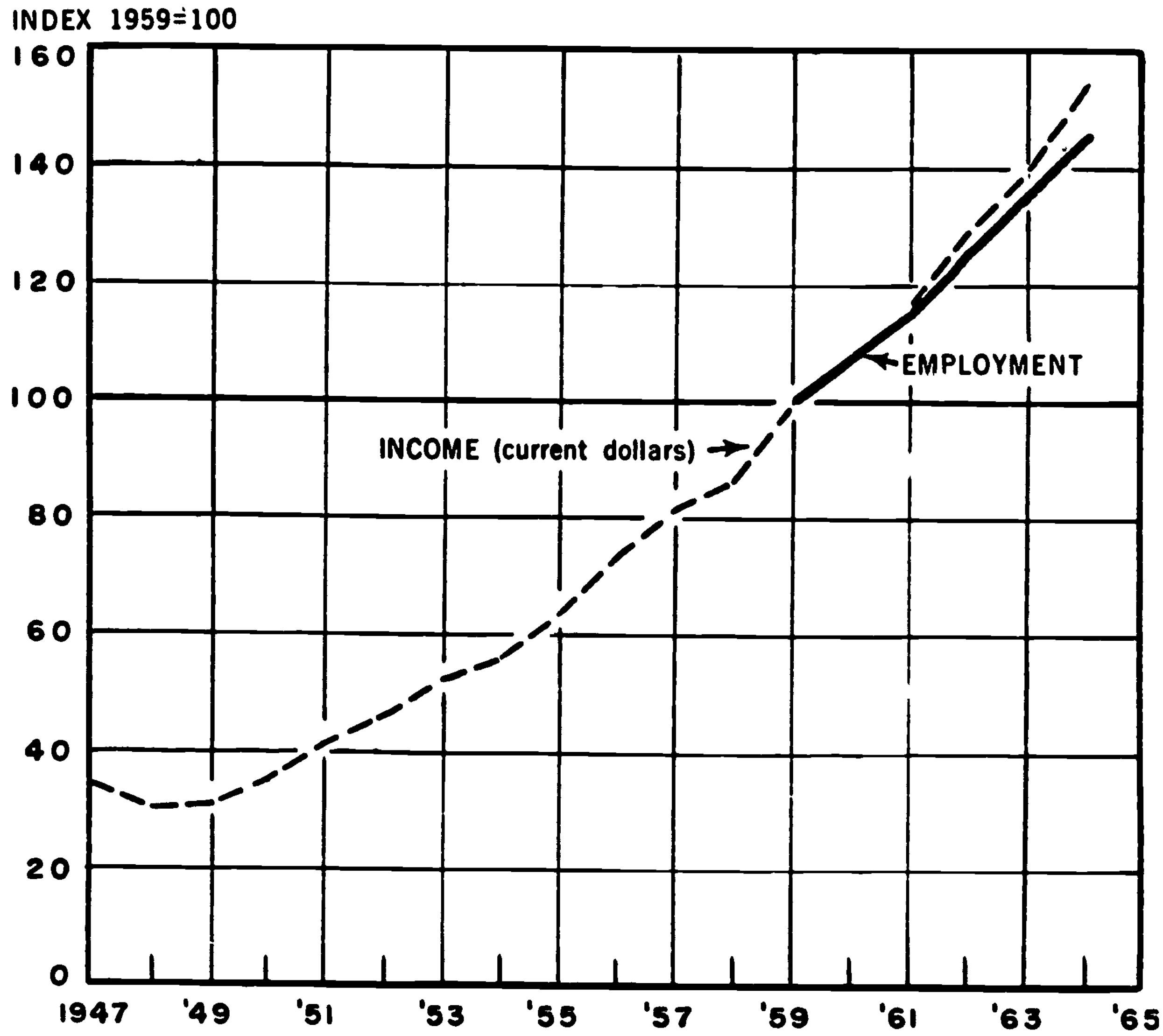
Employment trends varied within the rapidly increasing "other business services" segment. An estimated 68 percent employment rise in research and development laboratories occurred in response to a general increase in research and development activity. Employment in business and management consulting firms increased by two-thirds because of the growing complexity of industry and commerce. On the other hand, employment in news syndicates is believed to have declined

[56] BLS employment (payroll) data are not available for this major industry group for the years prior to 1959 (benchmark data).

[57] Includes the following industries: news syndicates; private employment agencies; and business services not elsewhere classified (establishments engaged in research, development, and testing on a commercial basis; business and management consulting; and other business services, such as airplane rental, photographic developing, and fingerprinting).

EMPLOYMENT AND NATIONAL INCOME ORIGINATING IN MISCELLANEOUS BUSINESS SERVICES, 1947-64

	Employment (in 000's)
March 1959	670
March 1960	N.A.
March 1961	779
March 1962	847
March 1963	913
March 1964	980



Sources: Employment, Bureau of Labor Statistics; national income, Office of Business Economics

slightly, in part, because of improvements in communications and transportation.

1964-75. Manpower requirements in this major industry group are expected to rise by about four-fifths between 1964 and 1975, to almost 1.8 million. This rapid rise in employment requirements is expected mainly because of rising levels of business activity. However, employment requirements among individual industries will be influenced by a variety of factors. For example, rapid employment growth in establishments furnishing services to dwellings and other buildings will be stimulated by increases in the number of commercial buildings and the trend to contract services for window washing, floor waxing, office cleaning, and other janitorial services. Employment in credit reporting and collection agencies should be stimulated by population growth and rising personal income.

Effects of Technological Developments on Future Employment

Technological innovations are not expected to have a significant impact on employment requirements in this major industry group in the decade ahead.

The average miscellaneous business services establishment is relatively small. Many firms lack the financial resources needed to acquire major laborsaving equipment. In addition, many miscellaneous business services establishments perform functions that do not lend themselves to mechanization and automation. However, employment requirements in establishments such as those providing advertising, business and management consulting, and duplicating services may be adversely affected by the introduction of new and improved equipment.

Automobile Repair, Automobile Services, and Garages (SIC 75)

Summary

Employment requirements in the automobile repair, automobile services, and garages major industry group are expected to increase from 308,000 in 1964, to about 400,000 in 1975. Employment requirements are expected to grow almost as rapidly as motor vehicle registrations, with technological developments having only a slightly adverse effect on employment growth.

Employment Trends

1959–64. Employment in automobile repair, automobile services, and garages major industry group increased from about 240,000 in 1959 to approximately 308,000 in 1964.[58]

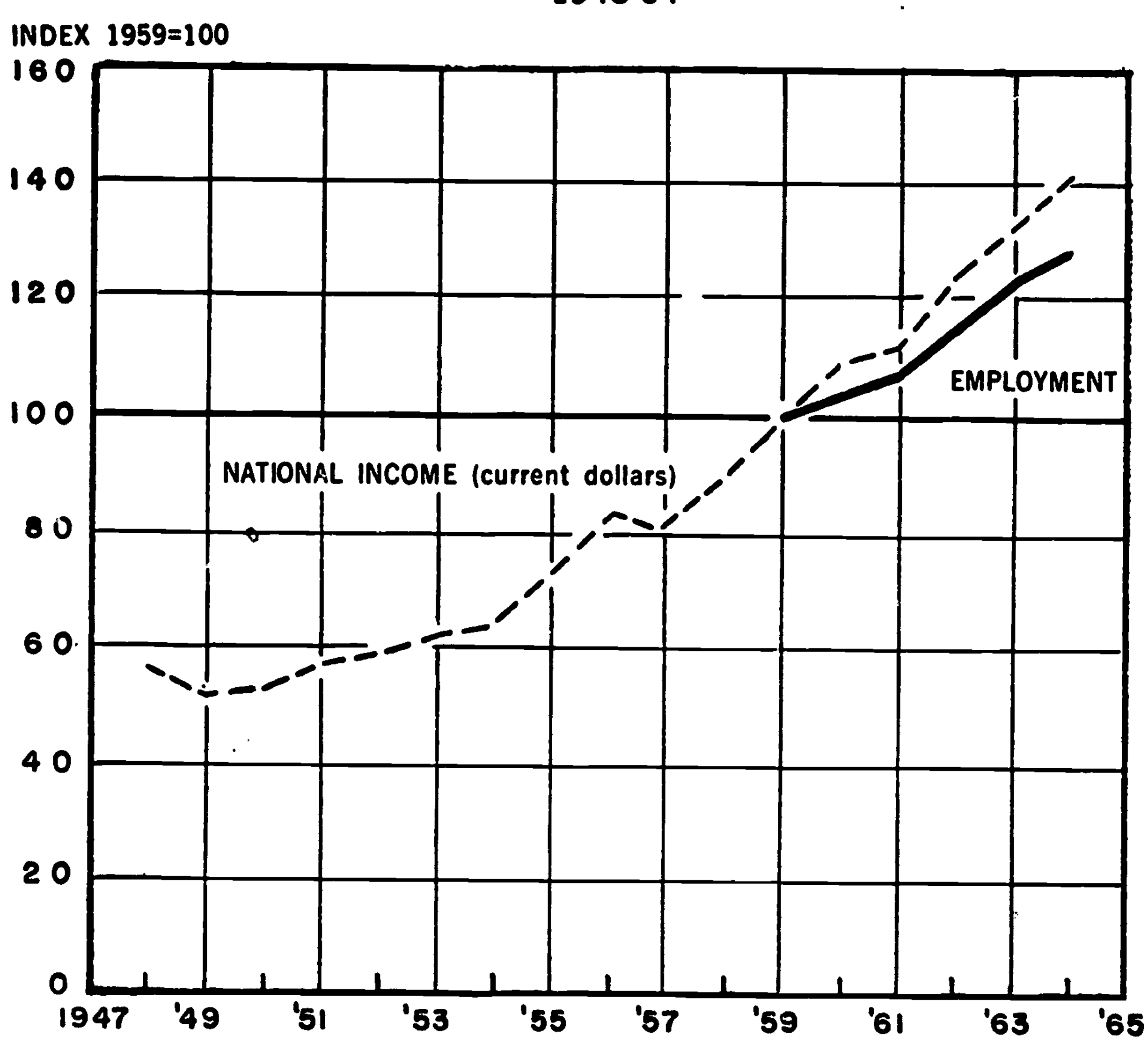
[58] BLS employment (payroll) data for this major industry group are not available for the years prior to 1959.

In 1964, almost four of every five workers in this major industry group were employed in auto repair shops and establishments providing auto services such as inspection, washing, polishing, towing, and driving instruction. The remaining workers were employed in auto parking and auto rental establishments in about equal numbers.

Employment in auto rental establishments grew very rapidly (almost 73 percent) between 1959 and 1964, mainly because of increases in business and pleasure travel, accompanied by the growing practice of renting and leasing motor vehicles. Employment in the auto repair and services industries, combined, increased rapidly between 1959 and 1964 (about 28 percent) and, because of their large size, accounted for nearly 80 percent of the new jobs in the major industry group. The significant employment increase was primarily a re-

EMPLOYMENT AND NATIONAL INCOME ORIGINATING IN AUTOMOBILE REPAIR, AUTOMOBILE SERVICES AND GARAGES, 1948-64

Employment (in 000's)	
March 1959	240
March 1960	N. A.
March 1961	260
March 1962	277
March 1963	297
March 1964	308



Sources: Employment, Bureau of Labor Statistics; national income, Office of Business Economics sult of the rising demand for auto repairs generated by the growing number and complexity of automobiles. Between 1959 and 1964, automobile registrations increased from about 59.6 million to 71.9 million or by 20 percent.[59] The growing popularity of items such as automatic transmissions, power steering, and air conditioning increased the complexity of automobiles during the late 1950's and early 1960's. For example, the proportion of new automobiles equipped with factory-installed air conditioners almost tripled between the 1959 and 1964 automobile model years.[60]

In contrast to the rapid employment growth in the auto rental and auto repair and services establishments, employment in auto parking establishments increased only slightly (about 3 percent) between 1959 and 1964. The relatively slow employment growth in auto parking resulted from the rapid increase in the number of self-service parking lots and suburban shopping centers offering free parking.

1964–75. Employment requirements in the automobile repair, automobile services, and garages major industry group are expected to increase to 400,000 by 1975, an annual growth rate of 2.4 percent compared with 5.1 percent between 1959 and 1964. Employment growth will result primarily from the growing number and complexity of automobiles. Registrations of automobiles are expected to increase by about 30 percent by 1975, to more than 93 million. The demand for automobiles will be spurred by rising population and new household formations, increased consumer purchasing power, and more multicar ownership.

However, employment will increase less rapidly than in the past because of the growing competition from auto dealers for the auto repair market, greater emphasis on replacement rather than repair of auto parts, and increases in output per worker resulting from job and repair shop specialization and the application of laborsaving technology. In recent years, the introduction of extended maintenance warranties on new automobiles has tended to tie buyers of new automobiles to dealers for service.

While most of the new job openings in this major industry group will occur in the auto repair and services sector, establishments renting automobiles should continue to have the fastest rate of employment growth. The demand for rental automobiles will be stimulated by increases in business and pleasure travel. Air travel, a major factor in the demand for rental automobiles, is expected to become increasingly popular.

Although a substantial increase in the number of parking establishments is anticipated in the years ahead, employment in these establishments is expected to continue to grow slowly, because of the anticipated rapid increase in the number of suburban shopping centers and self-service parking operations.

Effects of Technological Developments on Future Employment

Technological developments are expected to have only a slightly adverse effect on employment growth in this major industry group through the mid-1970's. The major impact of technology will be on employment in establishments engaged in automobile repair and services where the more widespread use of laborsaving devices and improved operating procedures are expected to reduce labor requirements moderately and change job characteristics.

The increasing use of test equipment such as dynamometers and engine analyzers may slow the employment growth of mechanics by reducing the time needed to diagnose malfunctions and check the quality of repairs. The increasing use of power tools and special purpose tools—such as pneumatic wrenches and cutting tools, transmission jacks, and tire changers—will reduce labor time needed to disassemble and assemble automobile components, thus limiting the growth in employment of mechanics, body repairmen, tire changers, and general garage laborers. The need for car washers may be reduced as a result of increases in the number of self-service car wash facilities and improvements in mechanized "car laundry" equipment.

A recent development is the emergence of large automobile repair shops that feature production-line diagnosis of automobile malfunctions. In these shops, diagnosticians who are skilled in operating dynamometers and other types of test equipment determine needed repairs and route automobiles to mechanics who are specialists in a particular kind of repair work. Although relatively few large automobile repair shops presently use production-line diagnosis, the number may increase significantly during the next decade. As a result, the employment of diagnosticians and mechanic specialists may increase faster than the employment of all-round mechanics.

Increasing output per worker resulting from the more widespread use of laborsaving devices and improved operating procedures will be offset to some extent by greater maintenance requirements stemming from the trend toward greater complexity in automobiles. During the next decade, a growing proportion of automobiles is expected to be equipped with air-conditioners, power steering, crankcase and exhaust emission control devices,

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[59] *Automobile Facts and Figures, 1965*, Automobile Manufacturers Association, 1965, p. 18.

[60] Ibid., p. 14; and *Automobile Facts and Figures, 1964*, p 14.

and other items that add to maintenance requirements and the need for mechanics. On the other hand, the need for automobile lubrication men is expected to decrease because an increasing proportion of the automobiles in use will require less frequent oil changes and chassis lubrications.

Miscellaneous Repair Services (SIC 76) [61]

Summary

Employment requirements in miscellaneous repair services establishments are expected to increase rapidly between 1964 and 1975. This growth will stem primarily from the Nation's growing stock of consumer durable goods, most of which require repairs at one time or another. Technological innovation is not expected to restrain employment growth significantly.

Employment Trends

1959–64. Employment in miscellaneous repair services establishments increased by slightly better than one-sixth between March 1959 [62] and March 1964, from about 124,000 to approximately 146,000.

In 1964, more than two-thirds of all employees in this major industry group were employed in "other miscellaneous repair shops." [63] The remaining workers were employed in establishments primarily engaged in the repair of electrical equipment, such as home appliances, television sets, radios, transformers, and electronic and electrical control equipment.

Between March 1959, and March 1964, employment grew by about one-fifth in "other miscellaneous repair shops" and by about one-eighth in electrical repair shops, mainly because of the rising stock of durable goods resulting from rising business and consumer expenditures. In addition, much of the equipment repaired by workers in these establishments increased in complexity, thus increasing labor requirements.

1964–75. Manpower requirements in miscellaneous repair services establishments are expected to rise by about two-fifths over the next decade, to about 205,000 in 1975.

The increase in employment requirements will result from increasing consumer purchases of electrical goods, including portable and color televisions, stereophonic and transistor radios, video tape recorders, and household appliances; and rising business expenditures for capital goods—virtually all of which require repair.

Rapid growth is expected in the number of radios, televisions, and phonographs in use. In 1964, more than 9 out of every 10 households had 1 or more television receivers. Over the next decade, the number of households with two or more television receivers is expected to increase significantly, mainly because of the growing demand for color, and portable television receivers. Other consumer electronics products that are expected to be used increasingly include stereophonic radios, phonographs, AM–FM radios, and portable transistor radios. New consumer products, such as home video tape recorders, as well as improved styling and design of existing products, will also stimulate demand. Greater use of nonentertainment products, such as closed-circuit television, two-way radios, and various medical electronic devices, also is expected.

In recent years, technological improvements in television receivers and radios (such as the use of transistors in place of tubes) have reduced the amount of repair service this equipment requires. On the other hand, there has been an increase in the care, skill, and technical knowledge needed to repair the more complex equipment in use. These technological developments are expected to increase employment of television and radio service technicians who have theoretical as well as practical knowledge of electronic circuits and know-how to use the latest test equipment. Servicing television receivers, radios, and related electronic equipment is a changing field, with constant technological advances.

The number of household appliances in use also is expected to increase rapidly during the decade ahead. Demand will be stimulated by the introduction of new types of appliances and by the improved styling and design of conventional appliances to make them more attractive and easier to operate. In addition, more widespread use of such appliances as electric can openers, waste disposers, home clothes dryers, knife sharpeners, and coin-operated dry cleaning machines is expected.

Employment requirements in other repair shops also are expected to increase. For example, in-

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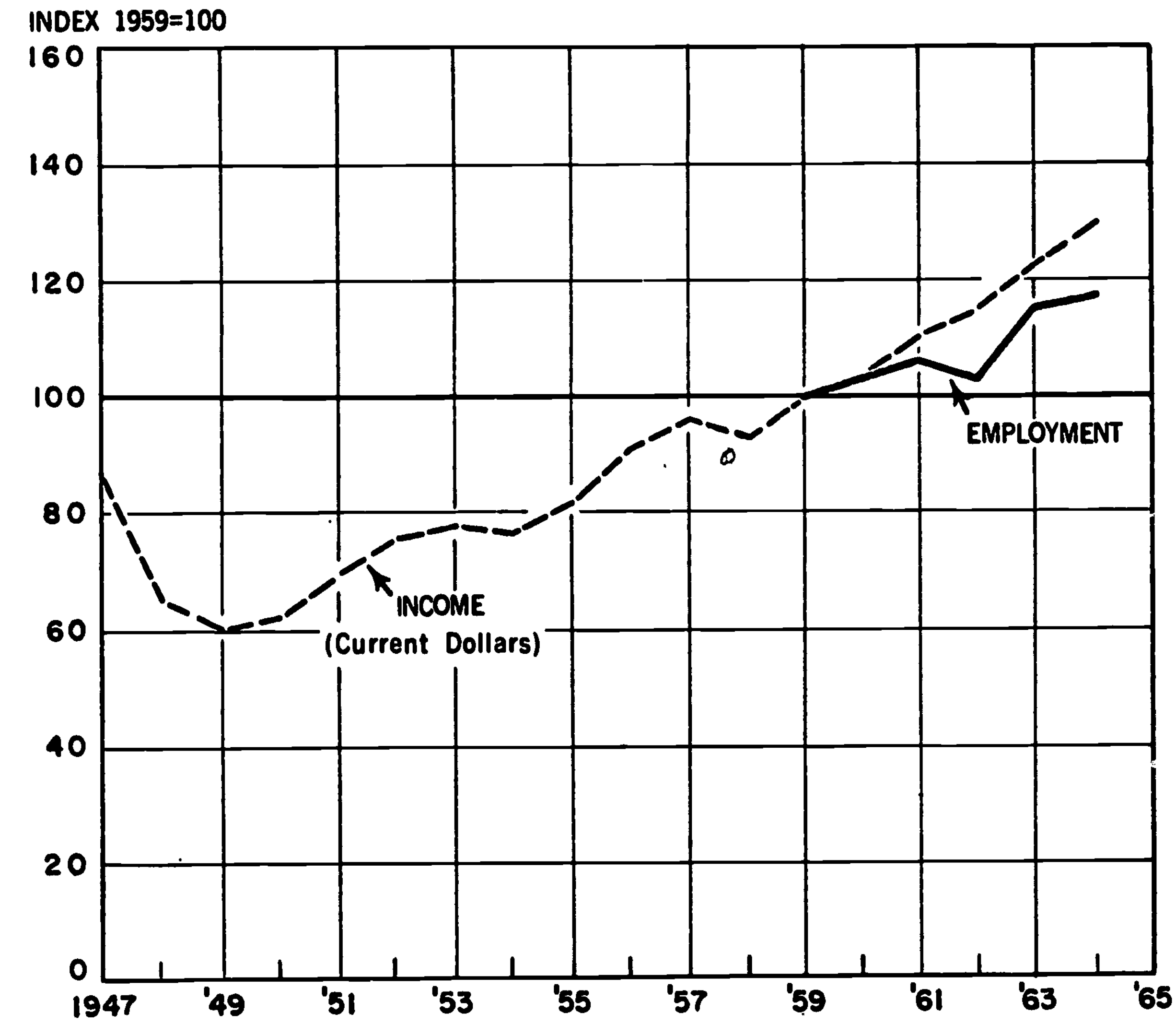
[61] This industry covers a miscellany of repair services performed primarily by independent owner-operators or by very small shops. A large part of the Nation's repair services are performed by workers in other industries.

[62] BLS employment (payroll) data are not available for this major industry group for the years prior to 1959 (benchmark data).

[63] Includes bicycle, leather goods, musical instrument, farm machinery, business machine, and reupholstery and furniture repair shops; locksmith and gun shops; armature rewinding shops; typewriter rental shops; and establishments primarily engaged in the repair of watches, clocks, and jewelry.

EMPLOYMENT AND NATIONAL INCOME ORIGINATING IN MISCELLANEOUS REPAIR SERVICES,1947-64

Employment (in 000's)	
March 1959	124
March 1960	N.A.
March 1961	132
March 1962	138
March 1963	144
March 1964	146



Sources: Employment, Bureau of Labor Statistics; national income, Office of Business Economics.

creased expenditures for the rental or purchase of musical instruments, such as electrically powered organs and guitars, is expected because of rising personal spendable income, more leisure time, and a rapid increase in the number of young people. Increases in the rental and purchases of typewriters and various other business machines will stimulate the demand for repairmen. In addition, growth in both the number and complexity of machines used on farms will stimulate requirements of farm equipment repairmen.

Effects of Technological Developments on Future Employment

Technological innovations are not expected to limit significantly the growth in employment requirements in miscellaneous repair services establishments. A rapid increase in the number of machines in use will more than offset expected increases in output per worker. A continued increase in research and development activities should result in many new and improved products for both industry and the consumer. Although many of these products will be designed for more efficient repair, the number in use is expected to more than offset these gains. In addition, the small size of many repair shops tends to limit the extent to which laborsaving innovations can be introduced. In 1963, for example, more than 70 percent of the miscellaneous repair services establishments were operated by proprietors with no employees. The remainder averaged about four workers per establishment. However, employment requirements will be adversely affected to some extent by the manufacture of products that can be sold at prices competitive with the cost of repair. For example, an increasing number of watches are in use that can be replaced for less than the cost of repair.

Medical and Other Health Services (SIC 80)

Summary

Employment requirements in medical and other health services establishments (excluding government services) are expected to increase by more than one-half between 1964 and 1975, rising to about 3.1 million in 1975. The employment of technicians and subprofessionals will expand greatly both to supplement professional workers and to operate the many new and improved technological devices.

Employment Trends

1958–64. Employment in medical and other health services establishments increased by two-fifths, from nearly 1.5 million to 2.1 million, between 1958 [64] and 1964.

In 1964, more than two-thirds of the workers in medical and other health services establishments were employed in hospitals. The remaining workers were employed in establishments (other than hospitals) that provided medical services, such as medical and dental laboratories; sanatoria, convalescent homes, and rest homes; offices of doctors, dentists, and optometrists; and associations providing medical or other health services to their members.

Between 1958 and 1964, employment increased most rapidly (46 percent) in establishments (other than hospitals) that provide medical and health services. Factors affecting this growth were: (1) expanding population, including increasing proportions of very young and very old people who most need medical care; (2) increasing expenditures for medical care; (3) expanding medical services resulting from new medical techniques and drugs; (4) increasing interest in preventive medicine and the rehabilitation of the handicapped; (5) expanding medical research on the causes and prevention of physical and mental diseases; and (6) the extension of medical insurance plans. Employment in hospitals increased about 38 percent during the 1958–64 period, stimulated by such factors as a rise in the number of hospital beds and admissions; the rapid extension of hospital insurance programs; advances in medical technology in hospitals; and expansion in the range and volume of services provided by hospitals.

1964–75. Manpower requirements in this major industry group are expected to rise by more than one-half between 1964 and 1975. The requirements will be stimulated by the same factors as in the recent past. In addition, the new Medicare program, provided by the Social Security Amendments of 1965, will enable more persons to receive medical care in hospitals and nursing homes. Additional workers will be required to staff the newly created community mental health centers currently being built under the Mental Retardation Facilities and Community Mental Health Centers Construction Act of 1963. Health workers will be needed to help staff the regional health centers as provided by the Heart Disease, Cancer, and Stroke Amendments of 1965. Increasing expenditures on medical research also will stimulate employment, particularly of professional and technical workers.

Worker requirements in hospitals are expected to increase by about half between 1964 and 1975. Increasing numbers of hospital workers will be required to operate new and improved instruments and devices such as complex X-ray equipment, blood plasma equipment, artificial kidneys, and artificial pacemakers for the human heart. In addition, a continuing reduction in hours worked would require additional workers to maintain 24-hour hospital care. On the other hand, certain new developments in medical treatment, such as the use of antibiotics, will reduce the need for hospitalization or shorten the length of a patient's stay in a hospital. Because these treatment developments may lessen the amount of services provided per hospital patient, they may tend to offset, to some degree, the greater emphasis on worker requirements resulting from technological change.

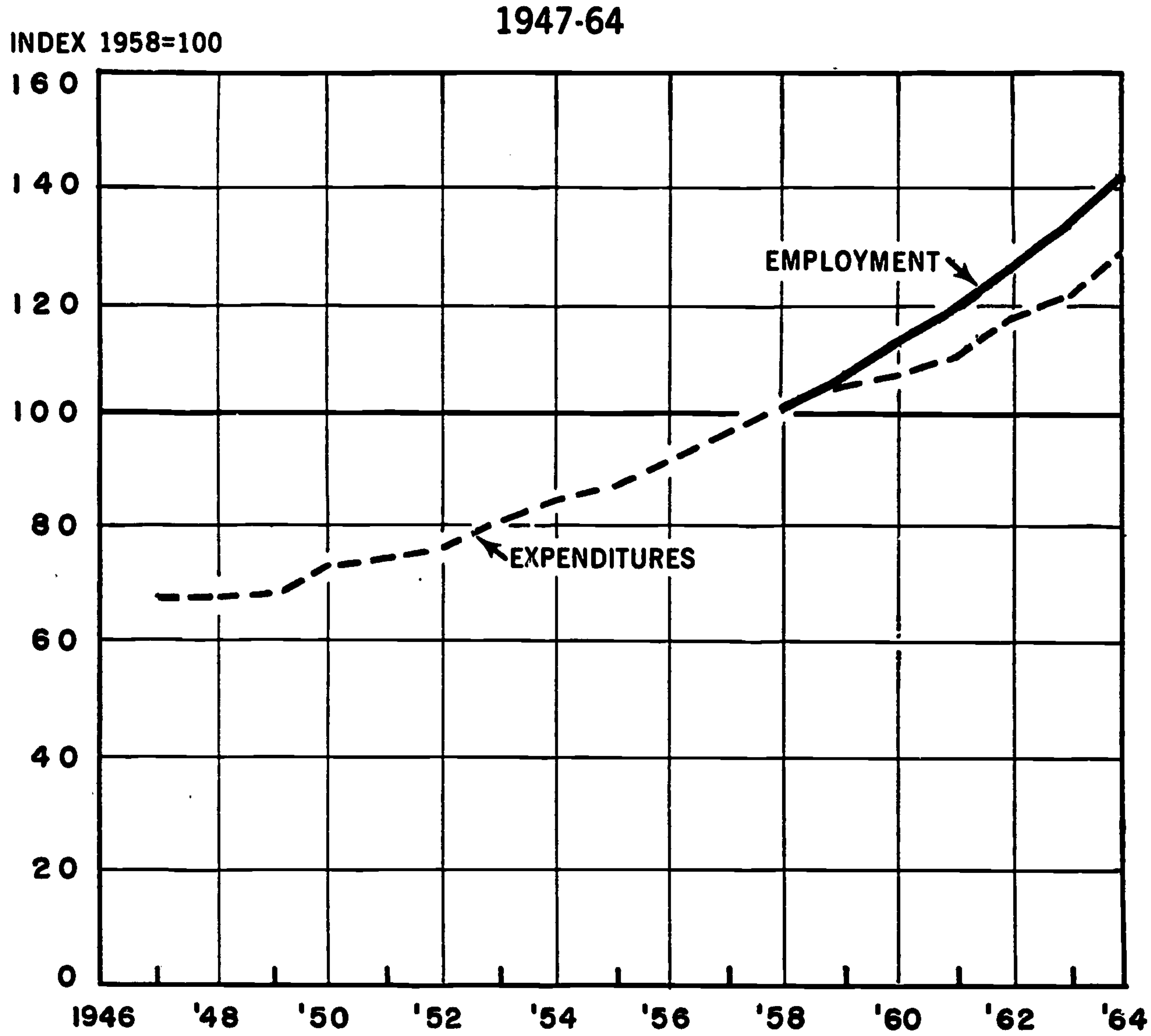
Effects of Technological Developments on Future Employment

Medical progress is expected to result in new occupations and the need for additional medical and health workers. However, it may also lead to a reduced need for certain types of workers. More medical technologists, medical X-ray technicians, and similar types of workers are expected to be needed to help operate new complex medical electronic devices such as electronic computer systems that automate blood testing, electronic flowmeters regulating the flow of human blood during heart-lung operations, physiological monitoring equipment, and electronic microscopes, as well as other complex nonelectric equipment, such as hyperbaric pressure chambers. Growing numbers of

[64] BLS employment (payroll) data are not available for this major industry group prior to 1958.

EMPLOYMENT IN MEDICAL AND OTHER HEALTH SERVICES AND PRIVATE CONSUMER EXPENDITURES FOR MEDICAL CARE, 1947-64

Employment (in 000's)	
1958	1,465
1959	1,555
1960	1,649
1961	1,742
1962	1,842
1963	1,941
1964	2,061



Sources: Employment, Bureau of Labor Statistics; expenditures, Office of Business Economics.

workers also will be needed to help apply new and improved techniques, such as transplanting organs and performing surgery by laser beams. Data processing, which is reducing the need for such workers as bookkeepers, business machine operators, and cashiers, is, however, increasing the need for workers to operate and maintain computers and related equipment.

Computers also are being used on an experimental basis for diagnosis, patient care, and medical research in a few hospitals. A recently developed computerized system that stores and retrieves medical information could help alleviate shortages of medical record librarians. The growing use of disposable plastic and paper surgical gloves, caps, masks, hypodermic needles, and other hospital items is expected to reduce the need for workers who perform laundry and sterilization duties. Furthermore, new hospitals will increasingly incorporate laborsaving innovations, such as a new tray-assembly line that reduces the need for certain types of kitchen workers.

Other technological developments in the medical services industries are expected to require increasing numbers of workers for various purposes. More pharmaceutical workers will be needed to dispense newly discovered drugs such as anti-blood-clotting agents, drugs that lower elevated blood pressure levels, and new psychoactive drugs administered to mental patients. Also growing numbers of physical therapists and occupational therapists will be needed to apply new techniques and devices to help patients regain physical, mental, or emotional stability.

Educational Services (SIC 82)

Summary

Employment requirements in private educational services are expected to increase very rapidly between 1964 and 1975. Technological developments are not expected to affect employment growth significantly through the mid-1970's.

Employment Trends

1959–64. Employment in private schools, colleges and other educational services increased from 748,000 in March 1959, to 909,000 in March 1964, an increase of 22 percent.[65]

In 1964, nearly three-fifths of the workers in this activity worked in private colleges, universities, professional schools, and junior colleges. About a third of the workers were employed in private elementary and secondary schools. The remaining workers were in libraries, correspondence and vocational schools, and specialized non-degree-granting schools such as dancing schools.

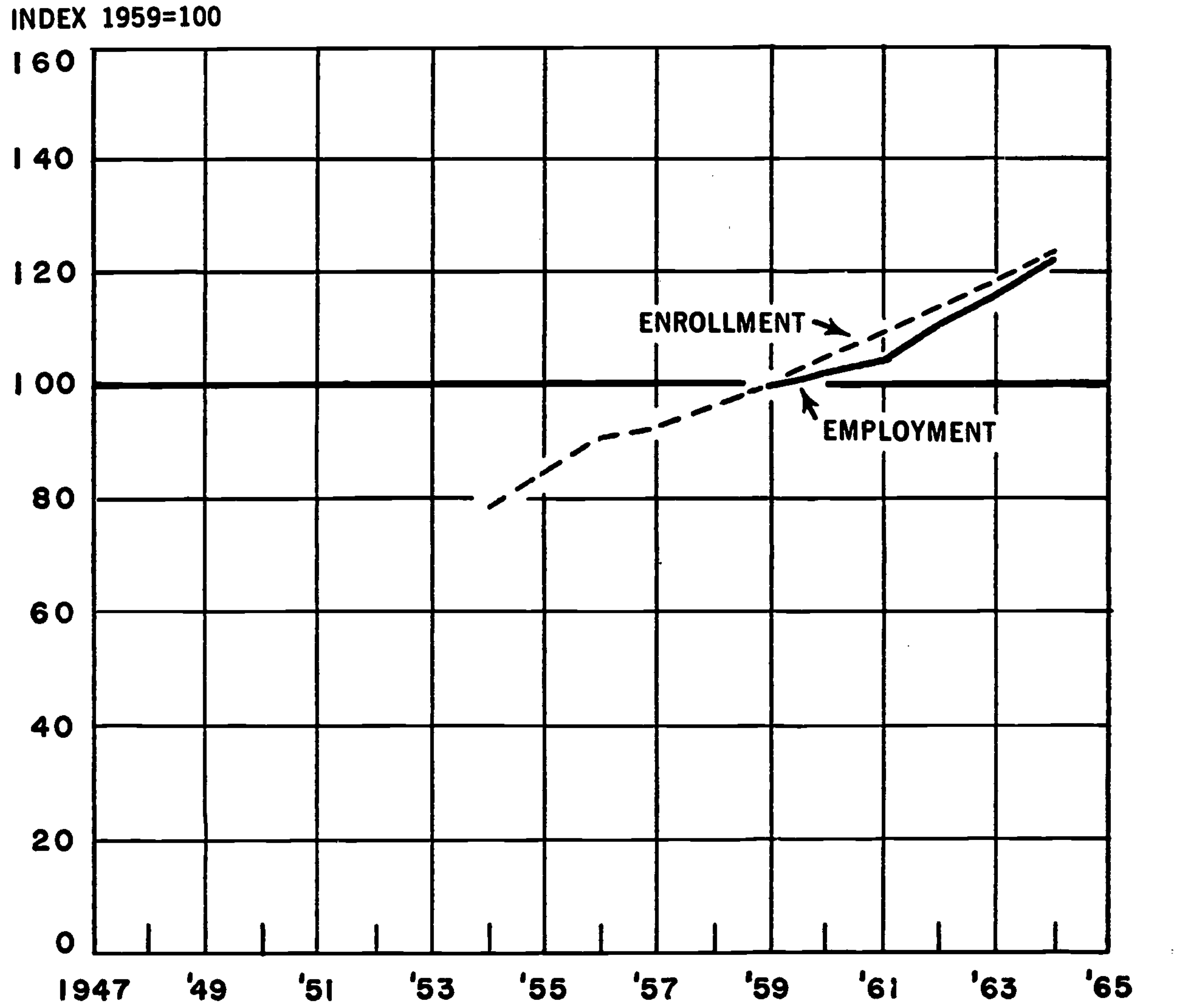
Between 1959 and 1964, employment in the private elementary and secondary schools and in the private colleges and universities, professional schools and junior colleges each increased about 22 percent. Employment increased only half as fast in the remaining educational establishments in this major industry group during the same period.

The growth in employment was the result of increasing population of school-age individuals. The high birth rates of the 1940's brought unprecedented increases in elementary school enrollments in the early 1950's. By the mid-1950's, these children were beginning to enter high schools, and in the early 1960's colleges were feeling the full force of this impact. Further-

[65] BLS employment (payroll) data for this major industry group are not available for the years prior to 1959 (benchmark data).

EMPLOYMENT AND ENROLLMENT IN EDUCATIONAL SERVICES, 1954-64

Employment (in 000's)	
March 1959	748
March 1960	N.A.
March 1961	784
March 1962	826
March 1963	864
March 1964	909



Sources: Employment, Bureau of Labor Statistics; enrollment, U.S. Office of Education.

more, the proportion of young people of high school age and college age who attend school has been increasing.

1964–75. Manpower requirements in private educational services are expected to rise by slightly more than 50 percent between 1964 and 1975, to about 1.4 million.

This significant increase in employment will be needed to meet the anticipated large growth in school enrollments resulting from the continued rise in the school-age population and the increasing proportion of young people of high school and college age who will be attending school. More young people are completing high school and going to college because of the rising educational requirements for work in our rapidly changing economy. The expected greater availability of scholarships and loans may also be a stimulus to increased enrollments in private schools. Moreover, the minimum age at which young people may leave school may be raised in some States. The anticipated continued rise in family income and, therefore, the ability to pay for education, is another factor that is anticipated to stimulate enrollments in private educational institutions.

Effects of Technological Developments on Future Employment

Technological developments are expected to affect the number and characteristics of jobs in education through the mid-1970's.

Technological innovations in the field of education have been primarily in the form of instructional television and teaching machines. Instructional television is used in mass instruction through motion pictures and television. It has two broad categories of programs: (1) cultural and informational programs aimed primarily at adult audiences, (2) televised lessons that are part of a school or college curriculum. Many schools are already using educational television despite differences of opinion over its value.

Teaching machines, designed to present information mechanically and to test student responses to the materials covered, are also being considered for use as a teaching aid. In 1963, about 6 million public and private elementary and secondary school students used some type of programmed instruction. This was considerably higher than the 3 million of the previous year and 250,000 of just 6 years ago.

Although educational television and teaching machines are expected to be used increasingly, it is unlikely that they will significantly affect employment requirements for teachers. Experience of the past few years suggests that they are not being used as teacher substitutes. It is hoped by educators that increased use of these teaching aids along with clerical help and teacher aides will free the teachers from much routine work. However, greater use of these technological innovations will increase employment requirements for professionally and technically trained individuals to develop instructional materials and programs.

The growth of clerical worker requirements will be slowed somewhat by the increasing use of computers and other data processing equipment.

Government Employment (SIC Division I)

Summary

Employment requirements in government are expected to increase at a somewhat faster rate in the next decade than between 1947 and 1964, mainly because of the services required by a rising population. State and local government employment is expected to increase rapidly and Federal Government employment only slowly. Technological change is expected to moderate employment growth.

Employment Trends

1947–64. Total government employment increased about 75 percent between 1947 and 1964, from 5.5 million in 1947 to 9.6 million in 1964. This rate of growth was much faster than the growth of total nonagricultural employment over the same period.

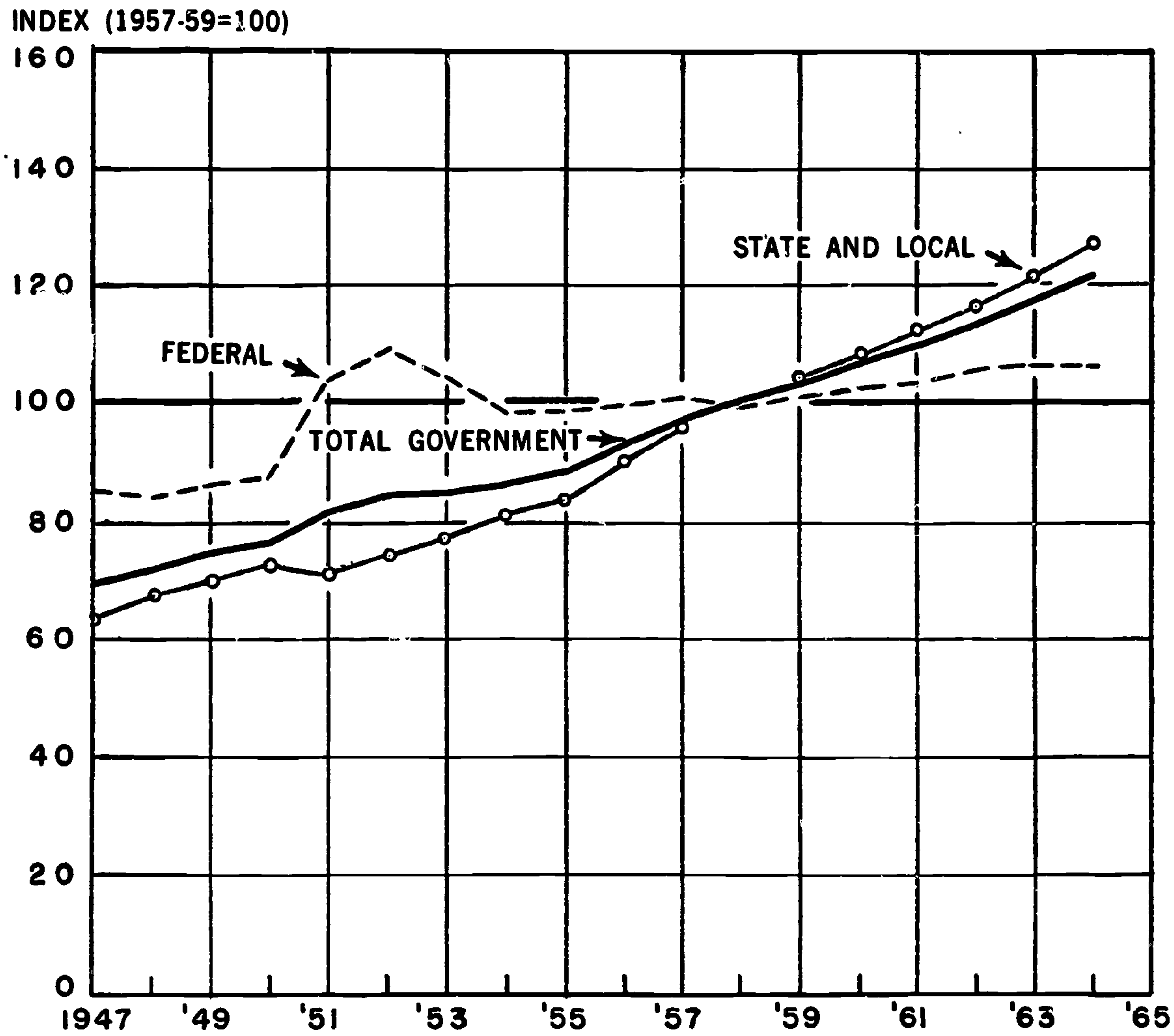
In 1964, nearly three-fifths of all government employment was in local government; about one-fourth in Federal Government; and the remainder in State government.

Growth in government employment in recent years, especially at [66] State and local levels, has been stimulated primarily by the rapid growth in population, the increasing proportions of the older

[66] "Trends and Outlook for Employment in Government," *Monthly Labor Review*, March 1965.

GOVERNMENT EMPLOYMENT: TOTAL FEDERAL, AND STATE AND LOCAL, 1947-64

Year	Employment (in 000's)
1947	5,474
1948	5,650
1949	5,856
1950	6,026
1951	6,389
1952	6,609
1953	6,645
1954	6,751
1955	6,914
1956	7,277
1957	7,616
1958	7,839
1959	8,083
1960	8,353
1961	8,594
1962	8,890
1963	9,225
1964	9,595



Source: Bureau of Labor Statistics

and very young people in the population, and the growing demand for more, and better, services.

Over the 1955–64 period, the greatest increase in government employment has been at the State level (59 percent).[67] This increase was due primarily to the very rapid growth in employment in educational activities. State employment in educational activities nearly doubled between 1955 and 1964. Rapid growth also occurred in local government employment (52 percent) where educational needs also provided the major impetus to employment growth. The rate of increase in State and local government employment in functions other than education resulted from a growing, increasingly urban population and the need to expand public health, sanitation, welfare, and protective services.

Federal Government employment increased by nearly one-fourth between 1947 and 1964. Most of the growth in civilian employment between 1947 and 1955 was occasioned by the country's military commitments. Defense Department employment increased by nearly 50 percent. Since 1955, Defense Department employment has decreased slightly, and growth in Federal Government civilian employment in recent years has been due to the creation of new agencies and programs, such as the National Aeronautics and Space Administration, and the expanding functions of established agencies.

[67] BLS employment (payroll) data are not available separately by State or local government for the years prior to 1955.

1964–75. Manpower requirements in government, primarily State and local, are expected to increase rapidly through the mid-1970's. By 1975, total employment requirements should be more than 50 percent above the 1964 level, more than twice the rate of growth projected for total nonagricultural employment requirements. As in recent years, State and local government will account for nearly all of this employment increase. The continuing rapid rise in population and the resultant increased demand for services is expected to result in sizable growth in employment in all major State and local government functions, including education, health and hospital care, sanitation, welfare, and protective services. Federal employment is expected to increase slightly through the mid-1970's, barring major increases in our military commitments. Most of the anticipated increase is expected to result from growth in nondefense programs.

Effects of Technological Developments on Future Employment

Technological developments such as automatic data processing, quick copy devices, data transmission and communications networks, and materials-handling equipment, are expected to have some impact on the number and characteristics of government employees. The primary impact is expected to be on employment in the Federal Government where centralization of functions lend themselves to wider use of these developments.

Federal Government (SIC 91)

Summary

Employment requirements in the Federal Government are expected to increase slightly through 1975. Growth in employment requirements will be limited to some degree by the expanding use of electronic data processing equipment, copying devices, and other laborsaving equipment.

Employment Trends

1947–64. Employment in the Federal Government increased from 1.9 million in 1947 to 2.3 million in 1964, an increase of about 24 percent.

In 1964, nearly 99 percent of all Federal civilian workers were employed in the executive branch of the Government. The legislative and judicial branches accounted for the remainder. This distribution of employment among the three branches of Federal Government has remained relatively unchanged during the post-World War II period.

Growth in total Federal civilian employment has resulted, in large part, from the growth of the Nation's military commitments. Employment in the Department of Defense, which accounted for two-fifths of total Federal civilian employment in 1964, increased 36 percent over the 1947–64 period. Most of this increase occurred between 1947 and the end of the Korean crisis. Since 1953, employment in this agency has declined by about 17 percent.

Post Office Department employment, which represented about 26 percent of all Federal civilian employment in 1964, increased by 28 percent between 1947 and 1964, as the total volume of mail handled increased by nearly 90 percent. Employment in this agency has remained relatively stable since 1961 due to the increasing mechanization of mail-handling equipment, the elimination of Saturday parcel post delivery service, and the decrease in the total number of post offices.

Federal civilian employment, other than that represented by the Department of Defense and the Post Office Department, rose by 11 percent between 1947 and 1964, as a result of the creation of new agencies and programs, and expansion of activities in existing agencies. Factors that have

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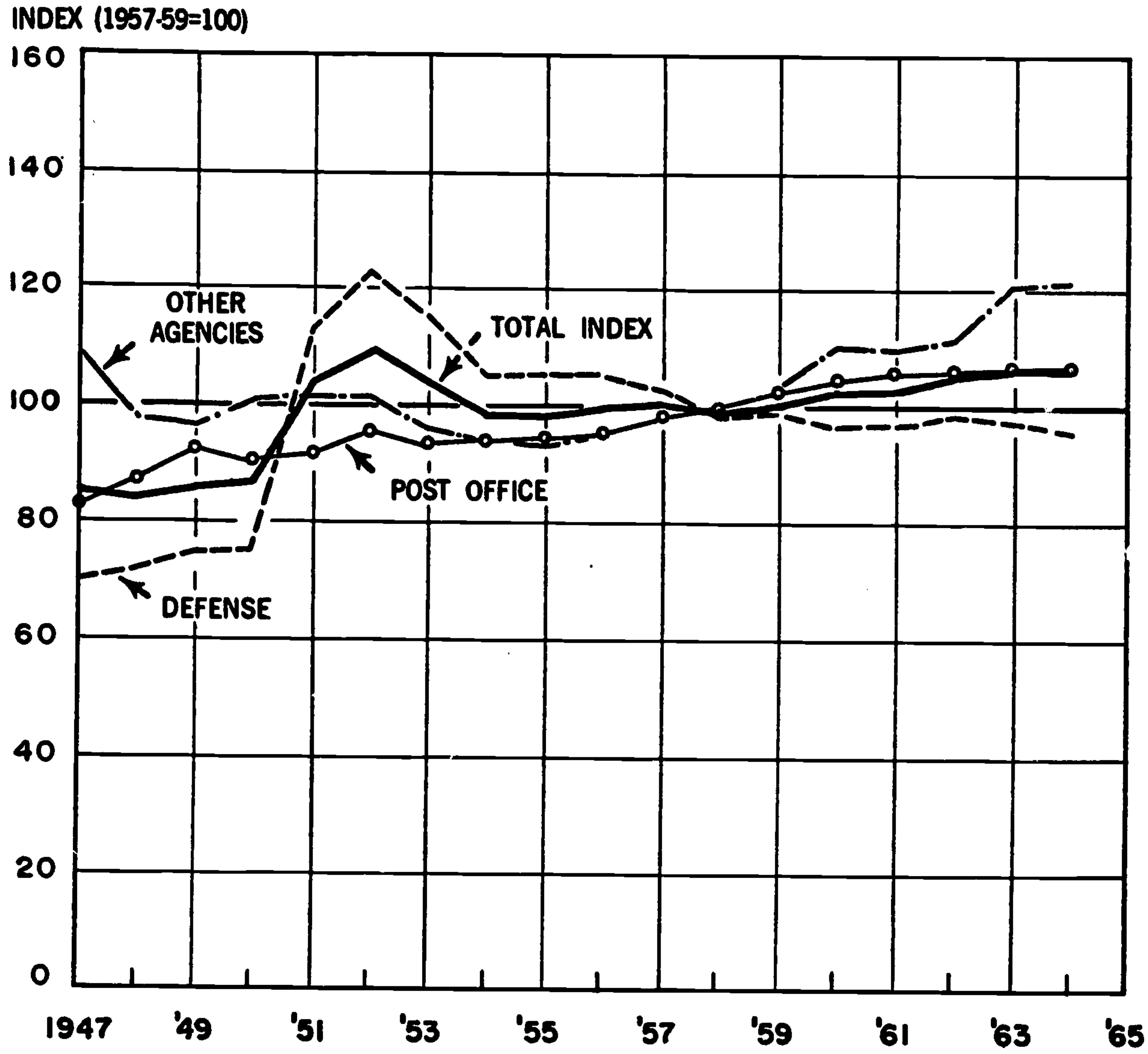
EMPLOYMENT IN THE FEDERAL GOVERNMENT : TOTAL, DEPT. OF DEFENSE, POST OFFICE, AND ALL OTHER AGENCIES, 1947-64

	Employment (in 000's)
1947	1,892
1948	1,863
1949	1,908
1950	1,928
1951	2,302
1952	2,420
1953	2,305
1954	2,188
1955	2,187
1956	2,209
1957	2,217
1958	2,191
1959	2,233
1960	2,270
1961	2,279
1962	2,340
1963	2,358
1964	2,348



Source: Bureau of Labor Statistics

contributed to this relatively slow growth include the drive for greater economy and efficiency; the provision for State and local government implementation of many recent programs provided by Federal legislation; the trend toward contracting-out to private organizations functions ranging from research and development to janitorial services; and the greatly expanding use of automatic data processing and other highly mechanized equipment.

1964–75. Employment requirements in the Federal Government are expected to increase by about 7 percent between 1964 and 1975, to 2.5 million.

Employment requirements in the various sectors of Government are expected to differ widely. Barring a major increase in military commitments, employment in the Defense Department is expected to decline slightly. Some of this decrease is expected to result from the growing use of automatic data processing equipment, materials handling systems, data transmission and communications networks, and improved cost control techniques.

Employment requirements in other agencies are expected to increase moderately. Additional manpower may be needed to implement recent legislation in such areas as medical care, civil rights, education and training, urban development, and transportation. Federal activity in the area of space research and technology should also increase the need for professional and technical workers in this area of specialization.

Effects of Technological Developments on Future Employment

Technological developments are expected to continue to affect the number and characteristics of Federal Government jobs through the mid-1970's. The more widespread use of laborsaving technological innovations should increase output per worker. For example, the application of computers to a wider variety of routine clerical tasks, such as tax-return processing, accounting, payroll preparation, check disbursing, and inventory control, will continue to adversely affect the need for clerical employees in these areas. The rapidly increasing use of quick-copy equipment will limit the requirements for typists. The extension and improvement of communications systems should reduce the need for telephone operators, as well as typists and other clerical personnel. In addition, the growing use of improved materials handling equipment will continue to reduce the need for laborers.

Labor savings resulting from the increasing application of computers, and other automatic and mechanical devices to Federal Government operations are expected to be partially offset by the need for programers, computer operators, and machine monitors. In addition, the increasing application of data processing equipment to scientific research in the fields of aerospace and atomic energy is expected to result in an increased need for scientists, engineers, and engineering aids in research and development activities.

State Government (SIC 92)

Summary

Employment requirements in State government are expected to almost double between 1964 and 1975. Although automatic data processing will be increasingly used, it is not expected to be a significant factor in limiting growth in State government employment requirements through the mid-1970's.

Employment Trends

1955–64. Employment in State governments increased from about 1.2 million in 1955 [68] to approximately 1.9 million in 1964—a gain of 59 percent.

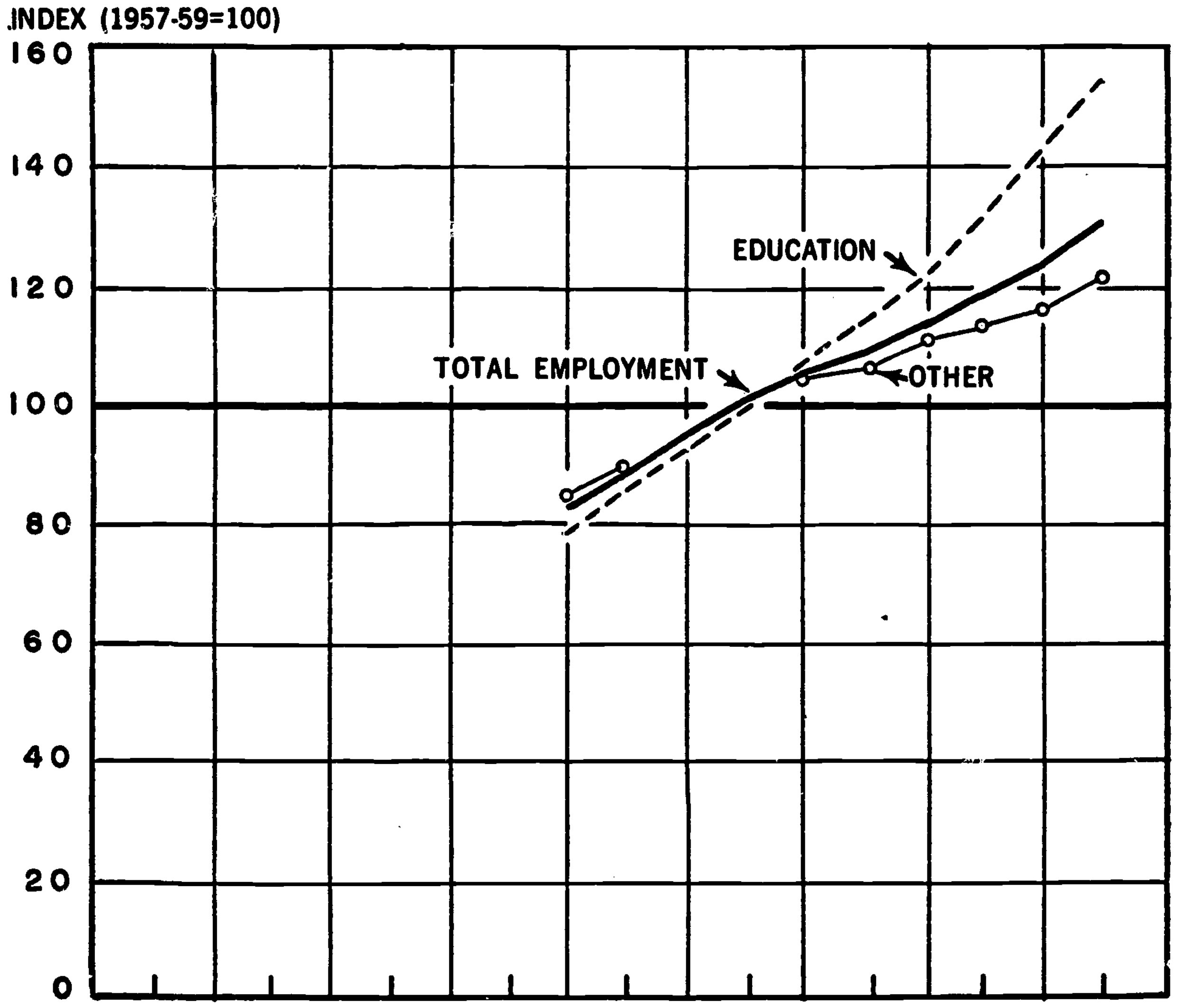
In 1964, educational functions accounted for approximately a third of all State government employment; hospitals, 21 percent; and highways, 17 percent. The remaining 30 percent was rather widely dispersed among other State government functions.

Between 1955 and 1964, employment in educational functions of State governments increased almost 98 percent, from 308,000 in 1955 to about 609,000 in 1964. Historically, the major portion of employment in State educational functions has been concentrated in institutions of higher educa-

[68] BLS employment (payroll) data are not available for State government for the years prior to 1955.

TOTAL EMPLOYMENT IN STATE GOVERNMENT, AND EMPLOYMENT IN EDUCATION AND IN OTHER GOVERNMENT FUNCTIONS, 1955-64

Employment (in 000's)	
1955	1,168
1956	1,250
1957	1,328
1958	1,415
1959	1,484
1960	1,536
1961	1,607
1962	1,668
1963	1,747
1964	1,856



Source: Bureau of Labor Statistics.

tion.[69] Employment in these institutions increased by 98 percent, during the same period, reflecting rising student enrollments.

Despite the increasing application of automatic data processing equipment, employment in State agencies dealing with financial and general administrative functions increased 44 percent between 1955 and 1964, as the expanding population made greater demands on these government functions.

1964–75. Employment requirements of State governments are expected to almost double (nearly 95 percent) between 1964 and 1975—growing considerably faster than during the 1955–64 period. The projected employment increase will result primarily from the need to expand existing services to meet the needs of a rapidly growing population, especially educational services. In addition, recently enacted Federal legislation, such as the Economic Opportunity Act, that provides for State implementation of Federal programs is expected to result in increased employment at the State level.

[69] U.S. Department of Commerce, Bureau of the Census, Annual Reports on *State Distribution of Public Employment.*

Effects of Technological Developments on Future Employment

Technological developments are not expected to have a significant effect on employment requirements in State government through the mid-1970's. However, the growing use of automatic data processing equipment for an ever increasing number of functions is expected to affect the occupational characteristics of many jobs in State government. Although fewer routine clerical workers will be needed for such activities as checking, posting, and maintaining records, the increasing use of automatic data processing equipment for more sophisticated purposes is expected to result in an increased need for management analysts and operators of this equipment.

Local Government (SIC 93)

Summary

Employment requirements at the local government level are expected to continue to increase rapidly through the mid-1970's. Because of the personal nature of many local government services, technological change is not expected to be a significant factor in limiting employment growth.

Employment Trends

1955–64. Employment in local government functions increased from about 3.6 million in 1955 [70] to 5.4 million in 1964, a growth of about 50 percent. Employment in educational functions, which accounted for over half of all local government employment in 1964, increased by more than 60 percent—from 1.8 million to 2.9 million. This category included administrative, clerical, professional and custodial staffs of elementary and secondary schools, technical and trade schools, junior colleges and colleges under the jurisdiction of municipalities, towns, counties, or special school districts. Although automatic teaching devices, such as instructional radio and television, and programed teaching materials designed to present information mechanically and to test the pupils' grasp of the materials presented, were beginning to be used, they have had no appreciable effect on employment growth in local educational functions in recent years.

Total employment in local government functions other than education increased by approximately 41 percent between 1955 and 1964. This increase resulted primarily from the rapid growth in total population. Also, the increasing concentration of the population in urban and suburban areas increased the need for additional utility services; police and fire protection; additional streets and highways; sewerage and other sanitary services, public housing, correctional services, and health and welfare services, etc.

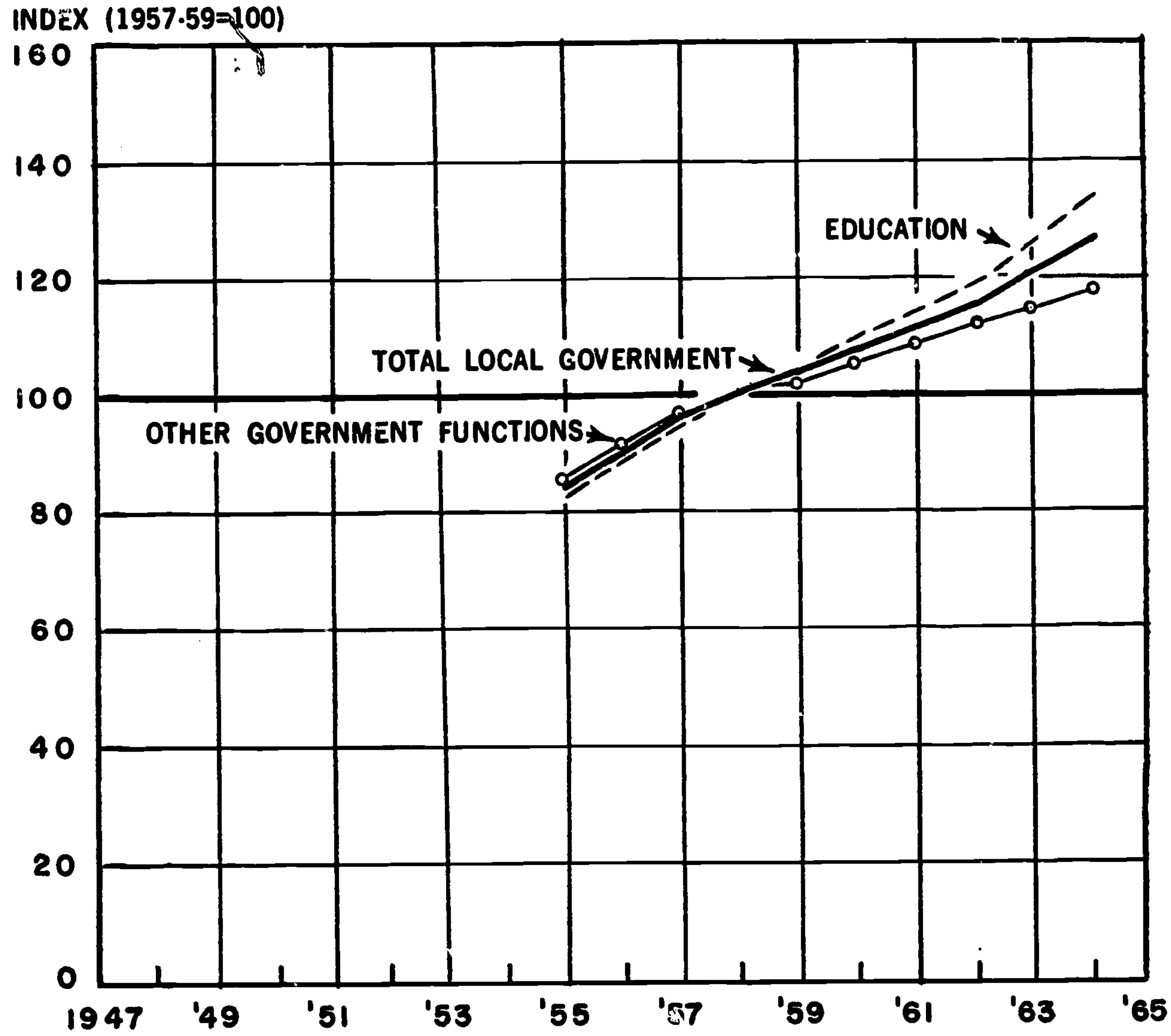
The growing proportions of elderly and very young persons in the population contributed to the expansion of employment in health and welfare and recreation services. Between 1955 and 1964, employment increased 60 percent in public welfare and hospital services and 70 percent in employment related to parks and public recreation. Employment in administrative and financial functions, however, increased only 3 percent reflecting the growing application of automatic data processing equipment in these areas, where it reduces the need for employees in such repetitive clerical tasks as posting, checking, and maintaining records.

1964–75. Employment requirements at the local government level are expected to continue to increase rapidly. By 1975, employment needs at this government level are expected to exceed 8.6 million, nearly two-thirds higher than the 5.3 million employed in 1964. The average annual rate of growth implied by the projection—about 4.6

[70] BLS employment (payroll) data are not available for local government for the years prior to 1955.

TOTAL EMPLOYMENT IN LOCAL GOVERNMENT, EMPLOYMENT IN EDUCATION, AND OTHER GOVERNMENT FUNCTIONS, 1955-64

	Employment (in 000's)
1955	3,558
1956	3,819
1957	4,071
1958	4,232
1959	4,366
1960	4,547
1961	4,708
1962	4,881
1963	5,121
1964	5,392



Source: Bureau of Labor Statistics

percent a year—is in line with the 1955–64 trend, and over two times as fast as total projected nonagricultural employment. As in the past, employment increases in local government are expected to result primarily from population growth.

Anticipated expansion of the economy and increasingly high levels of income will generate demands for such services as airports, parks, and recreation areas, and additional educational services. Employment in public educational functions is expected to increase over 40 percent. However, as a proportion of total local government employment, this category is expected to decrease somewhat as the rate of increase in the number of school-age persons in the population slows down.

Effects of Technological Developments on Future Employment

Major technological changes expected to affect employment in local government functions include the increasing use of automatic data processing equipment. Many local government agencies have used this equipment for some time to perform repetitive clerical tasks, such as payroll preparation and tax billing. More recently, however, there has been a trend toward the use of computer systems to provide factual information for use in planning, evaluation, and control of government programs. The increasing use of electronic data processing equipment for more sophisticated functions should boost employment requirements for computer operating personnel.

Additional technological changes, primarily in relation to the educational functions of government, are the use of instructional radio and television, and programed teaching materials. Instructional television, including cultural and informational programs, and televised lessons, is being introduced into the curricula of elementary and secondary schools, as well as colleges.

Programed teaching materials, designed to present information mechanically, and to test the student's grasp of the materials presented, are increasing in use. In 1963, about 6 million public and private elementary and secondary school students used some type of programed instruction—a 200 percent increase over the number of students using such equipment in 1957. However, the introduction of these automatic teaching devices is not expected to decrease the number of teachers through the mid-1970's.

Because of the increasingly high enrollments at all levels, the size of classes in many schools is too large to permit satisfactory instruction of pupils, and additional teachers will continue to be needed to reduce pupil-teacher ratios. The growing use of instructional television and programed teaching materials will provide some additional employment opportunities for some professional and technical workers. For example, the use of televised programs will require additional staff to do the research and other program preparation. In addition, some technical personnel will be required to operate and maintain the broadcasting equipment.

Statistical Note: Impact of Alternative Unemployment Assumptions on Projected Industry Requirements

The projections developed for this report assume a national unemployment rate of 3 percent in 1975. Different assumptions concerning the level of unemployment in 1975 could have been made. For example, for some purposes it might be useful to explore the implications of assuming a somewhat higher level of unemployment, say, 3.5 or 4 percent. For the whole economy, such a difference would merely equal the difference between a situation in which 97 percent of the labor force is employed and one in which either 96.5 or 96 percent is employed. Of course, changes in the rate of unemployment also have some effect on the size of the labor force.[71] However, the impact of higher unemployment assumptions would be greater for some industries than for others.

In order to evaluate the effects of alternative assumptions about unemployment, analysis of past periods was undertaken using correlation techniques. The analysis covered the impact of changing national unemployment rates on employment at various levels of industry detail. Overall, the analysis indicates the difference in projected employment in 1975 based on an unemployment assumption of 3 percent, compared with one of 4 percent, would be somewhat more than 1 million, including the effects of the lower unemployment rate on the size of the labor force. The analysis further indicates that more than half of any difference in total employment in 1975 resulting from a 1-percent lower unemployment assumption would be in manufacturing. Other industry groups that would account for significant proportions are trade, transportation and public utilities, and contract construction. Services, government, mining, and farming combined would account for less than a fifth.

Another indication of the impact of a different unemployment assumption may be obtained from an examination of the effects of alternative assumptions on projected levels of employment requirements by industry. For example, an assumption of 4 percent rather than 3 percent would lower projected manufacturing employment requirements by about 3.5 percent in 1975. An assumed national unemployment rate of 4 percent would have resulted in projected employment in trade being about 1 percent lower than at 3 percent, although the decline in trade would account for more than 10 percent of the total reduction in employment. In addition to manufacturing, employment requirements in contract construction, mining and transportation and public utilities would be more than 2 percent lower, if the unemployment assumption were raised a percentage point.

A number of cautions should be kept in mind in considering these relationships. For example, it should be kept in mind that the relationships applied to 1975 are based on experience in the post-World War II period when annual unemployment ranged from 2.9 percent to 6.8 percent of the civilian labor force. Excluding the Korean conflict period, unemployment did not fall much below 4.0 percent during this period. Using post-World War II relationships between unemployment and employment assumes that they would hold in a hypothetical situation not experienced since World War II (excluding Korean conflict years). The analysis is therefore most meaningful when used for evaluating the employment impact of changes in the unemployment rate at levels higher than 3 and 4 percent. There is, of course, more than one way national unemployment could be reduced. For example, it could be achieved through increasing government employment; through increasing aggregate demand; through structural programs, including education, retraining, and efforts to increase geographical mobility, or a combination of these. In this report no explicit assumptions were made concerning modifications of Government programs that might substantially affect the distribution of employment beyond the kind and magnitude of those that occurred during the historical period, such as the Neighborhood Youth Corps.[71a]

It should also be pointed out that the change in employment resulting from a reduction of the unemployment rate reflects primarily cyclical experience and will differ from long-run secular trends in the economy. It is these latter trends that are the major focus of the body of this report.

[71] See, Sophia Cooper and Dennis F. Johnston, "Labor Force Projections for 1970–80," *Monthly Labor Review*, February 1965.

[71a] Another approach to estimating the distribution of employment under alternative assumptions regarding the rate of unemployment, structure of demand, and level of output is used by the Bureau's Division of Economic Growth as part of the Interagency Growth Study Project. The projections developed by the Division of Economic Growth make explicit assumptions about specialized Government programs that may be expended in the course of reducing unemployment from 4 to 3 percent. Their report is expected to be released in the spring of 1966.

PART III. PROJECTIONS OF OCCUPATIONAL REQUIREMENTS IN 1975

Part III presents projections of occupational employment requirements in 1975 developed under the assumptions and using the methodology described in Part I. Like the industry projections presented earlier, the occupational projections presented here assume an unemployment rate of 3 percent in that year.

Projections to 1975 and accompanying materials are presented for the nine broad occupational groups—professional, technical, and kindred workers; managers, officials, and proprietors (except farm); clerical and kindred workers; sales workers; craftsmen, foremen and kindred workers; operatives and kindred workers; laborers (except farm and mine); service workers; and farmers and farm workers—and for a selected list of 28 detailed occupations. Statements on each occupation include discussions of past and projected manpower trends and a description of the factors expected to influence future requirements. The final section of each statement presents a more detailed description of the impact of technological changes on the occupation.

It should again be noted that the occupational projections which follow reflect requirements for workers in 1975 under the predicated assumptions, and are not meant to represent actual employment levels in 1975. Actual employment levels, of course, reflect the interaction of demand and supply. Since no attempt was made to assess the available supply for these occupations, the projected numbers must be viewed as representing needs and not employment.

Occupational Manpower Requirements in 1975

Significant changes have taken place and can be expected to continue to take place in the occupational structure of the U.S. labor force. One of the important changes of the post-World War II period has been the much greater growth in the number of workers in white-collar and service occupations as compared with manual workers, and especially the very large increase in the number and proportion of professional and high-level managerial workers. Employment of white-collar workers rose by more than one-half (54 percent) between 1947 and 1964, rising from less than 20.2 million to more than 31.1 million. Employment of service workers also rose substantially, growing from 6.0 million to 9.3 million, an increase of 55 percent. At the same time, employment of blue-collar workers increased much less rapidly, increasing about 8 percent, from 23.6 million to 25.5 million. The number of farm workers actually declined, falling from 8.1 million in 1947 to 4.4 million in 1964, a drop of 45 percent. (A more detailed discussion of employment trends in each of the broad occupational groups appears later in Part III.)

There are many factors which influence the occupational structure of the workforce. One of these major factors is technological change. Each industry has its own occupational pattern, and this occupational pattern has been and will continue to be heavily affected by new products and processes, increases in the sizes of plants, type of business organization, and other technological developments. A very important factor in the changes in the occupational structure of the economy is different rates of employment growth among industries, resulting from such influences as shifts in the distribution of income and changing patterns of consumption. The effect of the industry requirements (presented in Part II of this report) upon occupational needs was calculated through the use of the Bureau's occupation-industry matrix. Many other factors also affect the occupational structure, including growth in population and its changing age distribution; government policy—relating, for example, to the size of the defense and space programs, and to expenditures for research and development; institutional factors, such as union-management relationships and practices, as in the case of the railroad industry; and the relative supply of persons in different occupations and the substitution effect resulting from a shortage in one occupation and replacement by members of another, such as technicians for engineers. (A more comprehensive discussion of the factors influencing occupational employment appears in Part IV.)

Taking into account these diverse factors, the projections developed for this report indicate an increase of nearly two-fifths for white-collar jobs. Among white-collar occupations, the most rapid increase in requirements will be for professional and technical workers, which may grow twice as rapidly (54 percent) as the average for all workers. Requirements for clerical workers are also expected to increase rapidly, rising by nearly two-fifths, and sales workers, by nearly one-third. The demand for managers and officials is expected to rise somewhat more slowly, increasing less than one-fourth between 1964 and 1975.

Requirements for blue-collar workers are expected to rise by one-sixth between 1964 and 1975. Among the blue-collar workers, the most rapid increase in requirements will be for craftsmen, a rise of somewhat more than one-fourth, or about the average rate of increase for total employment as a whole. Requirements for operatives will increase more slowly, by about a seventh, and little change is expected in the demand for laborers.

A more than one-fifth decline in requirements is anticipated for farmers and farm workers.

As a result of these differential rates of growth, the occupational composition of the Nation's employment will be different in 1975 than it was in 1964. The major changes will be in the proportions of professional and technical workers, service workers, and clerical workers, all of which are expected to rise significantly, and in the proportions of farm workers, operatives, and nonfarm laborers, which will decline as a proportion of total employment. The remaining occupational groups will be roughly the same proportion in 1975 as they were in 1964.

The next sections of Part III describe in more detail the trends and projections for the broad occupational groups, and for the selected group of detailed occupations. It should be noted that the discussions of past employment trends in these occupations cover different periods of time. In the case of the broad occupational groups and a few occupations, data are available for many back years from the *Monthly Report on the Labor Force*. For other occupations, data are available only from the decennial *Census of Population* and are directly comparable only for 1950 and 1960; for still others, the only past data available are employment estimates for recent years prepared by the Bureau of Labor Statistics.

TABLE 2. MAJOR OCCUPATIONAL GROUPS OF WORKERS, ACTUAL 1964 EMPLOYMENT AND PROJECTED 1975 REQUIREMENTS

[Number in thousands]

Occupational group	1964 Employment		Projected 1975 Requirements		Percent change, 1964–75
	Number	Percent	Number	Percent	
Total, All occupational groups	70,357	100.0	88,700	100.0	26
White-collar workers	31,125	44.2	42,800	48.3	38
Professional and technical	8,550	12.2	13,200	14.9	54
Managers, officials, and proprietors	7,452	10.6	9,200	10.4	23
Clerical workers	10,667	15.2	14,600	16.5	37
Sales workers	4,456	6.3	5,800	6.5	30
Blue-collar workers	25,534	36.3	29,900	33.7	17
Craftsmen and foremen	8,986	12.8	11,400	12.8	27
Operatives	12,924	18.4	14,800	16.7	15
Nonfarm laborers	3,624	5.2	3,700	4.2	(1)
Service workers	9,256	13.2	12,500	14.1	35
Farm workers	4,444	6.3	3,500	3.9	–21

[1] Less than 3 percent.

NOTE: Projections assume a 3-percent level of unemployment in 1975. Percents do not add to totals due to rounding.

Professional, Technical, and Kindred Workers

Employment Trends

Employment of professional, technical, and kindred workers more than doubled between 1947 and 1964, rising from about 3.8 million to over 8.5 million. By 1975, manpower requirements for professional, technical, and kindred workers are expected to rise by more than one-half to 13.2 million. Employment requirements in this occupational group are expected to continue to be stimulated by a growing demand for goods and services resulting from population growth and rising living standards. Other factors that are expected to stimulate employment requirements include increases in government and private expenditures for research and development, highways, public buildings, medical care, education, and a great variety of other goods and services. It is anticipated that manpower needs will increase in practically every professional and technical field—including teaching, counseling, the natural sciences, engineering, programing, the health professions, the social sciences, and social and welfare work—but the rate of increase is likely to differ among these occupational fields.

Teaching, the largest profession, is expected to grow moderately to meet the needs of a rising school-age population and an expected increase in school attendance. The needs for elementary and secondary school teachers are expected to increase more slowly than for college and university teachers.

In engineering and natural science occupations, employment requirements are expected to increase substantially by 1975. Increased requirements are anticipated not only to meet the general needs of our increasingly complex and technologically oriented economy, but also as a result of the Nation's expanding research and development and technical assistance programs. Employment requirements for scientists are expected to grow faster than those for engineers.

Employment requirements for technicians are expected to grow rapidly over the 1964–75 period. The increasing emphasis on improved utilization of professional scientists, engineers, physicians, and dentists, and the need to relieve these workers of tasks that can be performed by less highly trained persons have been, and will continue to be, a major factor underlying the increased requirements for technicians.

Employment requirements in health service occupations are also expected to increase substantially. Among the factors underlying the expected increase are rising health standards, expansion of prepaid insurance plans, increasing interest in preventive medicine and rehabilitation of the handicapped, and an increase in medical research on the causes and prevention of disease.

Effects of Technological Developments on Future Employment

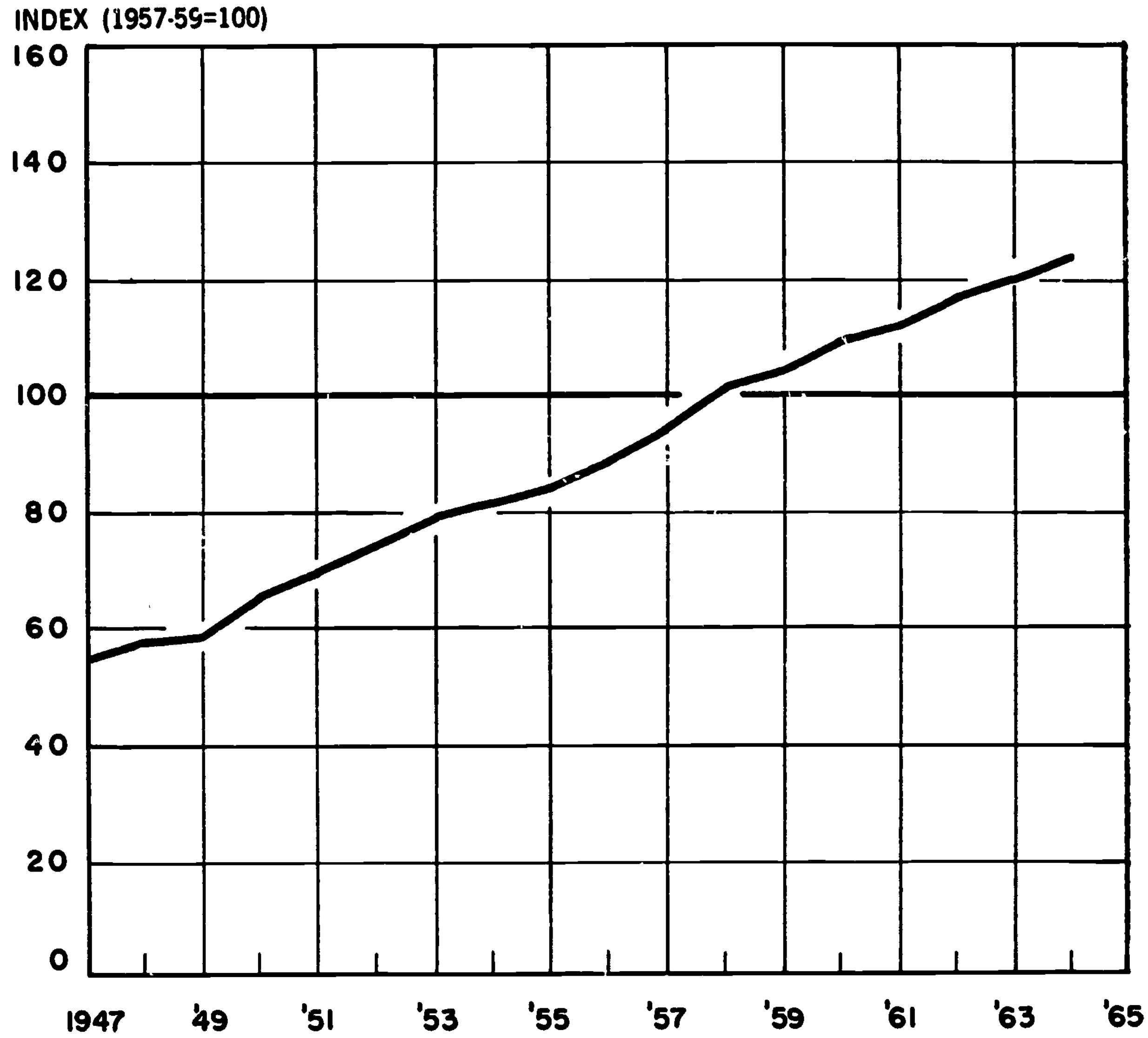
Technological developments will have a different impact upon employment requirements in the various professional, technical, and kindred worker occupations. For some occupations, such as programers, technological developments are expected to increase employment requirements. In other occupations, such as nurses and teachers, technological innovations may change the characteristics of the job rather than significantly affect employment in the field. In still others, such as draftsmen, technological change may hold down the growth of the field.

Employment in teaching is not expected to be affected significantly by changing technology. Technological innovations, mainly in the form of television for mass instruction, and teaching machines designed to present information mechanically and to test student responses to the materials covered, are expected to be used increasingly. These innovations most likely will not replace teachers but rather will assist them in improving teaching standards and in dealing with larger-than-usual groups of students. In fact, technological innovations in teaching may actually provide additional employment opportunities for workers in other occupations, such as writers, researchers, educational analysts, electronic technicians, computer programers, and broadcast engineers.

In engineering and the natural sciences, technological progress is expected to create many new areas of work for scientists and engineers, thus helping to bring about much of the anticipated increase in manpower requirements. The increasingly complex and rapidly changing technology of industry, exemplified by numerically controlled machine tools and other automated machinery, will create a need for many new engineers. However, other new technological developments, including

EMPLOYMENT OF PROFESSIONAL, TECHNICAL, AND KINDRED WORKERS, 1947-1964

Year	Employment (in 000's)
1947	3,795
1948	3,977
1949	4,028
1950	4,490
1951	4,788
1952	5,092
1953	5,448
1954	5,588
1955	5,792
1956	6,096
1957	6,468
1958	6,961
1959	7,143
1960	7,475
1961	7,705
1962	8,040
1963	8,263
1964	8,550



Source: Bureau of Labor Statistics

such laborsaving devices as desk computers, will relieve scientists and engineers of some of their routine tasks.

Technological advances in the economy as a whole also are expected to affect favorably the employment requirements for technicians. The increasing complexity of industrial products, processes, and machinery will create a need for additional workers who have some basic scientific and technical knowledge. The introduction of laborsaving equipment will somewhat offset this overall increase in needs in certain areas of work. For example, new automatic laboratory equipment may reduce the need for engineering, chemical, or physics technicians who perform routine but time-consuming laboratory tests. However, even the impact of these machines may be offset to some extent by the increased need for technicians to operate, maintain, and repair them, as well as to assist scientists and engineers in their development.

The anticipated rapid increase in requirements for programers will continue to be largely created by technological developments. As the fields of application for computers increase with improved and faster machines, growing numbers of programers will be needed to perform such varied assignments as keeping inventories, controlling production machinery in factories, making long-range weather forecasts, and analyzing air traffic patterns.

In the health field, the introduction of new technology is expected to result in the need for additional workers and in the creation of new occupations. Technological developments are expected to be most significant in hospitals, where more specialized medical technologists, medical X-ray technicians, medical and laboratory technicians, and similar types of workers will be needed to help operate new and complex medical electronic equipment, such as devices that automate blood testing, electronic flowmeters regulating the flow of blood during heart-lung operations, physiological monitoring equipment, and electronic microscopes. In most cases, the reason for the introduction of this new equipment is to improve medical care, rather than replace medical personnel. These technological developments may, however, limit slightly the growth in requirements for nurses, who formerly performed some of these functions, but, in general, the major impact on nurses will be to relieve them of routine tasks and permit them to spend more time in other types of work, thereby creating a change in the nature of their work more than affecting their employment requirements.

The following illustrative statements cover the employment trends and impact of technology for these occupations within the professional, technical, and kindred worker group: accountants, chemists, draftsmen, engineers, engineering and science technicians, physicians, registered professional nurses, and teachers.

Accountants

Employment Trends

Employment of accountants is estimated to have increased from 304,000 in 1950 to 440,000 in 1964. This increase resulted from a number of factors, including (1) greater use of accounting information in business management; (2) complex and changing tax systems; (3) growth in size and number of businesses; (4) increasing use of accounting services by small businesses; and (5) improved internal management of expanding government affairs.

An estimated one-third of all accountants work in independent accounting firms as proprietors, partners, or employees; about 10 percent work for Federal, State, or local government agencies; and the remainder are employees of business and industrial firms other than independent accounting firms.

Employment requirements for accountants are expected to rise by over 30 percent between 1964 and 1975, to about 565,000. The projected increase in requirements for accountants is based upon a continuation of the factors operating in the past. In addition, several new developments are expected to stimulate the demand for these workers. For example, growth of the number and activities of nonprofit institutions—charitable, health, and welfare organizations; pension and welfare funds; labor unions; educational institutions; churches; and clubs—may result in more financial reporting and the need for more accountants. Also, foreign investment and trade are expected to expand, providing additional employment requirements for accountants.

Effects of Technological Developments on Future Employment

The computer is expected to have a major effect on the accounting profession. Electronic data processing systems are expected to be used more and more, and manual bookkeeping and the manual preparation of trial balances, financial statements, and simple tax returns may be reduced. Computers can do this work faster and cheaper than people, and, as a result, the need for junior accounts who do lower level accounting work may be reduced or eliminated. On the other hand, computers provide vast quantities of data on receivables, sales, inventory, operating ratios, etc., which will require additional accountants to analyze. In larger companies, the computer is expected to bring about radical changes in information systems and decisionmaking processes. As the number of "total" information systems rise, additional highly trained accountants will be required to prepare, administer, and analyze the output of these systems.

Chemists

Employment Trends

Employment of chemists increased from an estimated 75,000 in 1950 to about 120,000 in 1964. One of the major factors underlying this rapid increase was the sharp growth in demand for products of industries that employ large numbers of chemists, particularly the chemicals and related products industry. (See statement on chemicals industry in Part II.) Increases in expenditures for research and development, in which nearly one-half of all chemists work, was another major factor in the employment growth of chemists. In addition, scientific discoveries in chemistry and other sciences opened whole new areas of employment for these workers, including plastics, rocket fuels, and a whole host of drugs and pharmaceuticals.

Chemistry is the largest natural science occupation, making up almost one-third of the total.

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Approximately three-fourths of all chemists were employed by private industry in 1964. The major industrial employer is the chemical manufacturing industry, which employs more than two-fifths of all chemists in private industry. Other manufacturing industries employing relatively large numbers of chemists are food, petroleum, electrical equipment, paper, and primary metals.

Significant numbers of chemists also are employed in wholesale and retail trade, by distributors of chemical, food, and petroleum products. Another relatively large group is employed by independent laboratories and research institutes providing consulting services.

Many chemists are employed in colleges and universities. Although most of these chemists teach, some work full or part time in research and development activities. Sizable numbers of chemists are employed by the government, primarily Federal Government agencies.

Employment requirements for chemists are expected to rise by more than three-fifths between 1964 and 1975, from 120,000 to nearly 200,000. Underlying the anticipated increase in the demand for chemists will be continued growth in expenditures for research and development. Such expenditures have increased very rapidly in recent years, and it is likely that they will continue to rise through the mid-1970's, although less rapidly than in the past decade. The growth in research and development expenditures is expected to result not only in the expansion of existing fields of work, but also in the creation of new types of work. For example, the discovery of new synthetic materials (such as acrylic fibers) has created a demand for chemists to develop uses for the new material. Other important factors underlying the expected increase in employment requirements for chemists include the growing demand for the products of industries that are major employers of chemists, especially for such products as plastics, synthetic fibers, drugs, fertilizers, and high energy fuels for missiles and rockets; the growing complexity of chemical products and the processes required to produce them; and the increased demands of a growing population for improved products such as better drugs.

Effects of Technological Developments on Future Employment

The development of laborsaving laboratory apparatus will tend to limit growth in employment requirements for chemists who do routine analysis and testing. For example, hydrocarbons can now be analyzed at high speeds through the use of gas chromotographs; and the amount of heat in a substance can be measured automatically by calorimeters. These instruments not only reduce the possibility of human error, but also produce results in a much shorter length of time. The major effect of such new equipment will be to free the chemist from routine testing, allowing him to devote more time to complex research and development work.

On the other hand, technological advancements both in the field of chemistry and in the economy as a whole will be a major factor contributing to the overall increase in employment requirements for chemists. Technological developments resulting from scientific advancements in such fields as nuclear energy and space exploration will increase the demand for chemists to develop new processes and products. For example, recent advancements in space exploration have created a need for chemists to develop more powerful rocket fuels, space foods, and waste disposal systems.

Draftsmen

Employment Trends

Employment of draftsmen more than doubled between 1950 and 1964, rising from about 125,000 to 260,000. The rapid growth in demand for the products of the durable goods industries, which employ large numbers of draftsmen, was a major factor underlying this increase. Another factor that contributed to employment growth was the large increase in the number of complex technical products requiring extensive plans and exact drawings in order to be produced. In addition, the rapid growth in other areas of work requiring large numbers of draftsmen—such as research and development, space exploration, and defense activities—was a major factor underlying the increase in employment over the 1950 to 1964 period.

The large majority of draftsmen—about 9 out of 10—are employed in private industry. The manufacturing industries that employ the largest numbers of draftsmen are the machinery, electrical equipment, fabricated metal products, and transportation equipment industries. Nonmanufacturing industries employing large numbers of draftsmen are engineering and architectural services, and construction.

Employment requirements for draftsmen are expected to increase by about two-fifths between 1964 and 1975, rising from 260,000 to about 375,000. However, this projected increase represents a significant slowing down of the rate of increase of the past decade and a half.

Among the factors underlying this projected growth is the continued expansion of industries employing large numbers of draftsmen. Requirements for draftsmen also are expected to rise as a result of the increasingly complex design problems of modern products and processes. Furthermore, as engineering and scientific occupations grow, more draftsmen will be needed as support personnel.

Effects of Technological Developments on Future Employment

Technological innovations will limit to some extent the increase in employment requirements for draftsmen generated by an increasing demand for drafting services. The major effect of laborsaving technological innovations in drafting will be on routine work such as tracing, rather than in the more complex design work.

Laborsaving technical innovations, such as new equipment for photoreproduction of drawings and electronic drafting, will eliminate some of the draftsman's time-consuming routine work. Drafting time also will be reduced because of the increasing use of new types of drafting paper that can be erased a number of times, thereby reducing the need to redraw an entire plan when design changes are made. Furthermore, computers have been developed that can interpret the engineers' specifications, design the product, and produce detailed lists describing materials needed to produce the object.

The use of laborsaving technological innovations is not expected to seriously limit growth in employment requirements for draftsmen over the next decade. Automatic drafting equipment is not yet available for use in the development of complicated drawings such as those in the field of electronics. Furthermore, computers and electronic plotting machines are very expensive; conversion costs are high; and integration of new machines with existing systems is difficult.

Engineering and Science Technicians

Employment Trends

Employment of engineering and science technicians (excluding draftsmen and surveyors) increased from about 450,000 in 1960 to 620,000 in mid-1964. The rapid growth in demand for products of industries that employ large numbers of technicians was a major factor underlying this increase. Another factor that contributed to the employment growth of technicians was the great increase in expenditures in areas of work requiring large numbers of technicians, such as research and development, defense, and space exploration. The increasing complexity of industrial products and processes also created a demand for more technically trained personnel.

Engineering and science technicians accounted for about 7 percent of all professional, technical, and kindred workers in 1964. About three-fourths of all technicians were employed by private industry. Large numbers were employed in the electrical equipment, machinery, chemical, aircraft and parts industries and miscellaneous business services industries. In mid-1964, the Federal Government employed approximately 75,000 engineering and science technicians. State and local governments employed another 60,000.

Employment requirements for engineering and science technicians are expected to increase by about two-thirds between 1964 and 1975, to more than 1,000,000. Among the factors underlying the increase in requirements for technicians will be the continued expansion of industries employing large numbers of technicians. It is also anticipated that the services of technicians will be used more extensively than in the past, as employers become aware that they can better utilize scientists and engineers by supplying them with additional support personnel. As products and the methods by which they are manufactured become more complex, increasing numbers of technicians will be required to assist engineers in such activities as production planning, maintaining liaison between production and engineering departments, and technical sales work. The anticipated growth in research and development expenditures is another factor underlying the expected increase in demand for engineering and science technicians. Such expenditures are expected to continue to rise through the mid-1970's, although less rapidly than they did in the past.

Expenditures for the defense and space programs also are of great importance to the demand for technical personnel. The level of such expenditures is not expected to change substantially in the years ahead, and, therefore, the demand for technicians in defense- and space-related work is not expected to change significantly. If the levels of such expenditures change substantially, however, the employment of engineering and science technicians would be affected accordingly.

Effects of Technological Developments on Future Employment

Technological innovations such as automatic laboratory equipment are expected to replace some types of technicians and increase the need for others during the years ahead. For example, the introduction of equipment such as Ph meters, calorimeters, spectrographs, and automatic analytical instruments may eliminate the need for technicians who perform routine repetitive experiments. However, other technicians will be required to operate and maintain this equipment, as well as assist in its development. Thus, much of the reduction in employment requirements for technicians resulting from technological change may be offset by the increase in requirements generated by the use of new equipment.

Technological developments resulting from scientific advancements also will create many new areas of employment for technicians in research and development work. For example, electronic technicians will be needed to assist space engineers in developing instruments that will operate in the extreme conditions of outer space. The employment of technicians also should increase as a result of the need to operate and repair this new and more complex equipment. Furthermore, the introduction of some new equipment will likely create whole new areas of work for technicians. For example, the electron microscope may create an increased demand for technicians to assist research scientists and engineers in the area of biochemistry and in the development work resulting from the research.

Engineers

Employment Trends

Employment of engineers increased more than 80 percent between 1950 and 1964, rising from an estimated 535,000 to about 975,000. One major factor in this increase has been the rapid growth in demand for products of industries employing large numbers of engineers. These industries include electrical equipment, machinery, aircraft and parts, and instruments. Many new scientific discoveries have resulted in new areas of work for engineers, such as nuclear energy, space exploration, and computer technology. Engineering time required to develop and produce products has increased, mainly because of the growing complexity of industrial products and production processes. Growth of Federal expenditures in areas of work requiring large numbers of engineers—including research and development activities—also has been a factor stimulating requirements for these workers.

Engineering is the second largest professional occupation, exceeded in size only by teaching; for men it is the largest profession. Manufacturing industries employ the largest number of engineers—more than one-half of all engineers in 1964. The manufacturing industries employing the largest number of these workers were the electrical equipment, aircraft and parts, machinery, ordnance, chemicals, instruments, primary metals, and fabricated metal products industries. About one-fourth of the engineers were employed in nonmanufacturing industries, primarily in the construction, public utilities, engineering and architectural services, and business and management consulting service industries.

Federal, State, and local governments employed approximately 140,000 engineers in 1964; about half of these engineers worked for the Federal Government. Educational institutions employed about 30,000 engineers in research as well as in teaching positions. A small number were employed by nonprofit research organizations.

Employment requirements for engineers are expected to rise by more than half between 1964 and 1975, rising from 975,000 to nearly 1.5 million. Among the factors expected to bring about the anticipated increase in demand for engineers are rising population, higher levels of income, and capital investment, which will result in expansion of industry to meet the demand for additional goods and services. Another factor that should lead to an increase in the demand for engineers is the expected continued growth of expenditures for research and development. Such expenditures increased very rapidly in recent years, and it is likely they will continue to rise through the mid-1970's, although less rapidly than in recent years. Growth in research and development activities will result both in the expansion of existing areas of work, and in the creation of new ones, especially in the fields of automated machinery and computers. Engineers are and will continue to be in the forefront of automation and technological change, and the growing automation and mechanization of industry will require large numbers of engineers to plan, develop, and build the processing machinery and equipment involved.

Because a large proportion of all engineers are engaged in defense and related work (estimated at about one-fourth of the total in 1964), the magnitude of future expenditures for defense and space programs will be important in determining the overall level of demand for engineers.

Effects of Technological Developments on Future Employment

Technological developments in the economy as a whole are expected to be a major factor contributing to the expected increase in employment requirements for engineers. Technological advancements resulting from scientific discoveries in such fields as computer technology, nuclear energy, and space technology will create many new areas of employment for engineers in development work. For example, in the field of space technology, additional engineers will be needed to design electronic instruments capable of withstanding conditions of outer space; in oceanography, engineers will be in demand to develop deep-diving maneuverable vehicles. The employment requirements for engineers also should increase as a result of the need to supervise the operation of the new, increasingly complex products resulting from this development work. For example, the use of computers capable of regulating traffic (through automatically controlled traffic lights) is expected to lead to an increase in employment of traffic engineers capable of using these computers. However, such effects will be offset to some extent by the displacement of engineers who worked on traffic regulation before the introduction of computers.

The rapid pace of technological change will result in more widespread use of engineers in administrative and managerial positions, as the increasing complexity of industrial processes creates the need for managers who can understand these processes. Furthermore, sales engineers will be required to discuss the technical aspects of a product or assist with its installation or use.

Some technological developments may, however, have the effect of reducing the needs for engineers in some areas of work. For example, the development of automatic testing equipment will likely reduce the need for quality control engineers. However, other types of engineers will be needed to design the automatic testing equipment, to supervise its production, sell it, install it, and maintain it. Thus, reduced employment requirements for engineers resulting from the introduction of labor-saving equipment probably will be offset by the increase in requirements generated by the development of the new equipment.

Overall, the effects of changing technology will be to increase the need for engineers. Nevertheless, some changes in the functions of engineers may result from technological developments. In the case of civil engineers, for example, much of the more routine computational work involved in designing a structure will be taken over by computers, leaving the engineer to concentrate on design and development work.

Physicians

Employment Trends

Employment of physicians increased by nearly one-third beween 1950 and 1964, rising from nearly 200,000 to about 265,000. The steady increase in employment of physicians resulted primarily from the expansion in population, particularly of very old and very young people who need medical care most. The expansion of medical insurance coverage has increased the need for physicians, as has the increasing public interest in preventive medicine and the growing demand for medical services generated by the Nation's rising standards of living and greater health consciousness. The growth in employment of physicians, however, was slowed by the limited capacity of medical schools.

Over 175,000 physicians were engaged in private practice in 1964. About 35,000 were interns or residents in hospitals, and nearly 12,000 held regular positions on hospital staffs. Approximately 20,000 physicians were serving as commissioned officers in the Armed Forces or were employed in Federal Government agencies, chiefly in hospitals and clinics of the Veterans Administration and the Public Health Service. The remainder were employed in private industry, State and local government health departments, medical schools, research foundations, and professional organizations.

Employment of physicians is expected to rise by nearly 15 percent between 1964 and 1975. It is expected that the growth in requirements for these workers will be much greater, but employment growth over this period will be limited by the capacity of medical schools. The factors underlying the expected increase in demand for the services of physicians include rising population, particularly in the old and young age groups; advances in medical science, such as the transplantation of human organs, the implanting of artificial organs, and development of new drugs; extension of prepayment programs for medical care and hospitalization (including a program for the aged provided by the Social Security Amendments of 1965); creation of community mental health centers under the Mental Retardation Facilities and Community Mental Health Centers Construction Act of 1963; and organization of regional health centers provided by the Heart Disease, Cancer, and Stroke Amendments of 1965. The demand for doctors also will be stimulated by growth in the fields of public health, health rehabilitation, and industrial medicine, as well as by the need to conduct medical research and to teach in medical schools.

Effects of Technological Developments on Future Employment

Technological developments in the field of medicine are not expected to significantly affect the employment requirements for physicians. The overriding factor affecting employment requirements is the expected increase in the need and ability to pay for medical and health services. In some areas of medical work, technological developments will tend to accelerate the growth in employment requirements. Among the technological innovations in the field of medicine that may increase the demand for physicians' services are new surgical techniques such as transplants of organs and tissues; new equipment, such as heart-lung machines; and the development and application of new drugs. Many more people are expected to seeks physicians' services as a result of the availability of these new methods of treatment.

Some technological innovations, however, may reduce slightly the growth in requirements for physicians. These include telemetry, a technique that makes possible distant readings of physiological functions (the symptoms of patients at home may be sent to a computer for analysis and the results relayed to the physician). In addition, the development of new vaccines and drugs will prevent, or limit the length of illnesses. In general, however, the impact of these new technological developments will ultimately enable physicians to spend more time in the treatment of other illnesses, thereby changing the pattern of physicians' services.

Registered Professional Nurses

Employment Trends

Employment of nurses increased by more than one-half between 1950 and 1964, rising from 375,000 to 582,000. The major growth factor was the increase in demand for hospital and other medical and health services resulting from the expanding population, the extension of medical insurance coverage, the growing expenditures by industry and Government for medical care, and rising standards of living.

Nursing is the largest profession in the health field. In 1964, about two-thirds of all nurses worked in hospitals and related institutions. More than 65,000 were private duty nurses who care for patients in hospitals and private homes, and about 47,000 were office nurses. Public health nurses in Government agencies, visiting nurse associations, and clinics numbered over 37,000; nurse educators in nursing schools, more than 20,000; and occupational health nurses in industry, nearly 19,000. Over 25,000 civilian nurses were employed by the Federal Government, and about 8,500 were serving as commissioned officers in the Armed Forces. Most of the remainder were staff members of professional nurse organizations or were employed by research organizations.

Employment requirements for nurses are expected to rise by almost 45 percent between 1964 and 1975, to more than 830,000. Among the factors that are expected to contribute to the increase in demand for hospital and health services and, therefore, the need for nurses are: (1) A growing population with a greater proportion of very young and old people, the age groups that need nursing care most; (2) rising standards of living; (3) growth in the number of persons covered by hospital and medical insurance programs, including the program for the aged provided by the Social Security Amendments of 1965; (4) expansion of medical services as a result of new medical techniques and drugs; and (5) the increasing interest in preventive medicine. In addition, an increasing number of nurses will be needed for rehabilitation work with the mentally handicapped, particularly in community health centers being established under the provisions of the Mental Retardation Facilities and Community Mental Health Centers Construction Act of 1963.

Effects of Technological Developments on Future Employment

Technological developments are not expected to significantly affect growth in employment requirements for nurses, but should affect their job characteristics. Some technological innovations will free nurses of many routine tasks, enabling nurses to devote more time to patients requiring special care. Other technological developments are expected to actually increase employment requirements for nurses by creating new areas of work.

Technological developments that should increase the employment requirements for nurses include the development and more widespread use of new drugs, medicines, and other treatments. Many more people are expected to seek medical help as a result of the availability of new methods of treatment, thereby creating a greater demand for nursing care. However, such effects of these developments will be offset to some extent by reductions in the periods of time patients are ill.

The most significant technological developments probably will take place in hospitals and related institutions, where new laborsaving equipment will tend to change the duties of nurses. Among the new developments are electronic monitoring devices that keep the nurse informed of a patient's condition, for example, his pulse and heartbeat and whether he is awake or asleep. Other laborsaving developments include the use of computers to record and analyze information about a patient's symptoms. Changes in hospital design and structure also will save time for nurses and enable them to provide better patient care.

Laborsaving technological developments outside the hospital include the portable electrocardiograph, which allows the nurse to take electrocardiograms in patients' homes and have them analyzed by a computer at a central health agency. Although this may reduce the time nurses spend with these patients, it probably will result in increased demand for such services.

Teachers

Employment Trends

Employment of public and private school teachers combined increased from an estimated 1.3 million in the 1954–55 school year to about 2.1 million in 1964–65. This employment growth resulted primarily from a great increase in the school-age population. In addition, the number of young people of high school and college age attending school has increased in recent years. At the beginning of the 1964–65 school year, about 53 million people—more than one-fourth of the country's total population—were enrolled in the Nation's schools and colleges, compared with about 35 million people in the 1954–55 school year.

Teachers make up the largest group of professional workers. In the 1964–65 academic year, more than half of all teachers were employed in elementary schools, more than a third in secondary schools, and about 10 percent in colleges and universities.

Employment requirements for teachers are expected to rise by almost a third during the 1965–75 decade, reaching about 2.7 million in the 1974–75 school year.[72] The projected increase in requirements for teachers is expected to result from continued growth of the school-age population and increasing attendance rates at the high school and college levels. Between the 1964–65 and 1974–75 academic years, enrollments are expected to increase by 8 percent in elementary schools, by 28 percent in high schools and by over 75 percent in colleges and universities. School attendance rates will be increasing because of the greater ability and willingness on the part of parents to pay for higher education, because of growth in family incomes; increasing availability of scholarships and part-time work; and increased expenditures for education provided for by recent Federal legislation, including the Elementary and Secondary Education Act of 1965.

[72] For further information, see "A New Look at Manpower Needs in Teaching," *Occupational Outlook Quarterly*, Bureau of Labor Statistics, May 1964.

Effects of Technological Developments on Future Employment

Technological developments are expected to have little effect on employment requirements for teachers through the mid-1970's. Technology has made limited inroads in the field of education, primarily through the use of instructional television and teaching machines. Instructional television is used primarily as a teaching aid in school or college curricula for the presentation of televised lessons. Teaching machines present information mechanically and test individual student responses to the materials covered. Even though both educational television and teaching machines are gaining in use, it is unlikely that they will have a significant effect on reducing the need for teachers. Such equipment will probably be used primarily to free teachers from many of their routine tasks and give them more time for individual assistance to students, and for improved preparation of lessons and teaching materials. As a result, technological innovations will change the job content of teachers' work more than it will affect overall employment requirements.

Managers, Officials, and Proprietors (Except Farm)

Employment Trends

Employment of managers, officials, and proprietors increased almost steadily between 1947 and 1964, rising from 5.8 million to about 7.5 million. However, employment trends among the occupation groups that make up this broad category varied sharply.

Employment of salaried managers and officials including industrial traffic managers, personnel workers, public relations workers, and purchasing agents rose rapidly between 1957 and 1964,[73] growing from about 3 million to about 4.3 million. The major reasons for this increase include the continuing growth in the size of business and manufacturing firms and the ever-increasing complexity of a wide variety of business functions. Technological developments also contributed to the employment growth, as an increasing number of technical managers were needed to perform such services as planning research and development programs, making policy decisions on the installation and use of automated machinery, and supervising automatic data-processing systems.

The number of proprietors, on the other hand, declined during the 1957–64 period, from about 3.7 million to about 3.2 million. The decrease in the number of proprietors resulted primarily from the replacement of small grocery and general stores and hand laundries (often run as family businesses) by supermarkets and large chains.

Employment requirements for managers, officials, and proprietors as a group are expected to rise by nearly one-fourth between 1964 and 1975, increasing from nearly 7.5 million to about 9.2 million. The major reason for this anticipated growth in requirements is the expected continuing increase in demand for goods and services resulting from a growing population and rising living standards, and the continued increase in the number and complexity of large business firms. As in the past, requirements for salaried managers and officials are likely to continue to increase substantially during the next decade because of the increasing dependence on trained management specialists—buyers, department store heads, and purchasing agents—by business organizations and Government agencies. In addition, occupations, such as hospital administrator, are developing, which will probably absorb some management and planning functions currently performed by nonmanagement personnel.

Although the number of proprietors declined substantially in the past, the number is expected to be at roughly the 1964 level in 1975. The trend toward formation of larger businesses is expected to continue to restrict the growth in the total number of firms. In addition, the replacement of small grocery and general stores and hand laundries by supermarkets and large chains is expected to continue, thus reducing the opportunities for proprietors. However, the greatest part of this shift from small proprietor-owned stores to larger businesses appears already to have taken place, and as a result, the decline in the number of proprietors is expected to be relatively small. Furthermore, offsetting this decline somewhat will be the expansion of business opportunities for proprietors in small franchised owner-operated businesses in such fields as quick-service grocery stores, self-service laundries and drycleaning shops, hamburger and frozen custard drive-ins, dance studios, and slenderizing salons. As a result of the diverse employment trends for salaried managers and officials, and proprietors, total requirements for this group may increase at about the same rate of increase as for all occupations—about one-fourth.

Effects of Technological Developments on Future Employment

Technological developments will have a different impact on employment requirements among the various occupations in the managers, officials, and proprietors category. The increasing use of computers in the processing of business and economic data and in the preparation of accounting and other business reports may limit somewhat the growth in demand for some middle-management positions. On the other hand, it is anticipated that technological advances will create a need for a growing number of technical managers and officials to perform such technical functions as planning scientific and engineering research projects for the development of new products and processes, supervising automatic data-processing systems, and training workers in new skills needed for new, complex machinery and techniques. Additional management personnel will also be

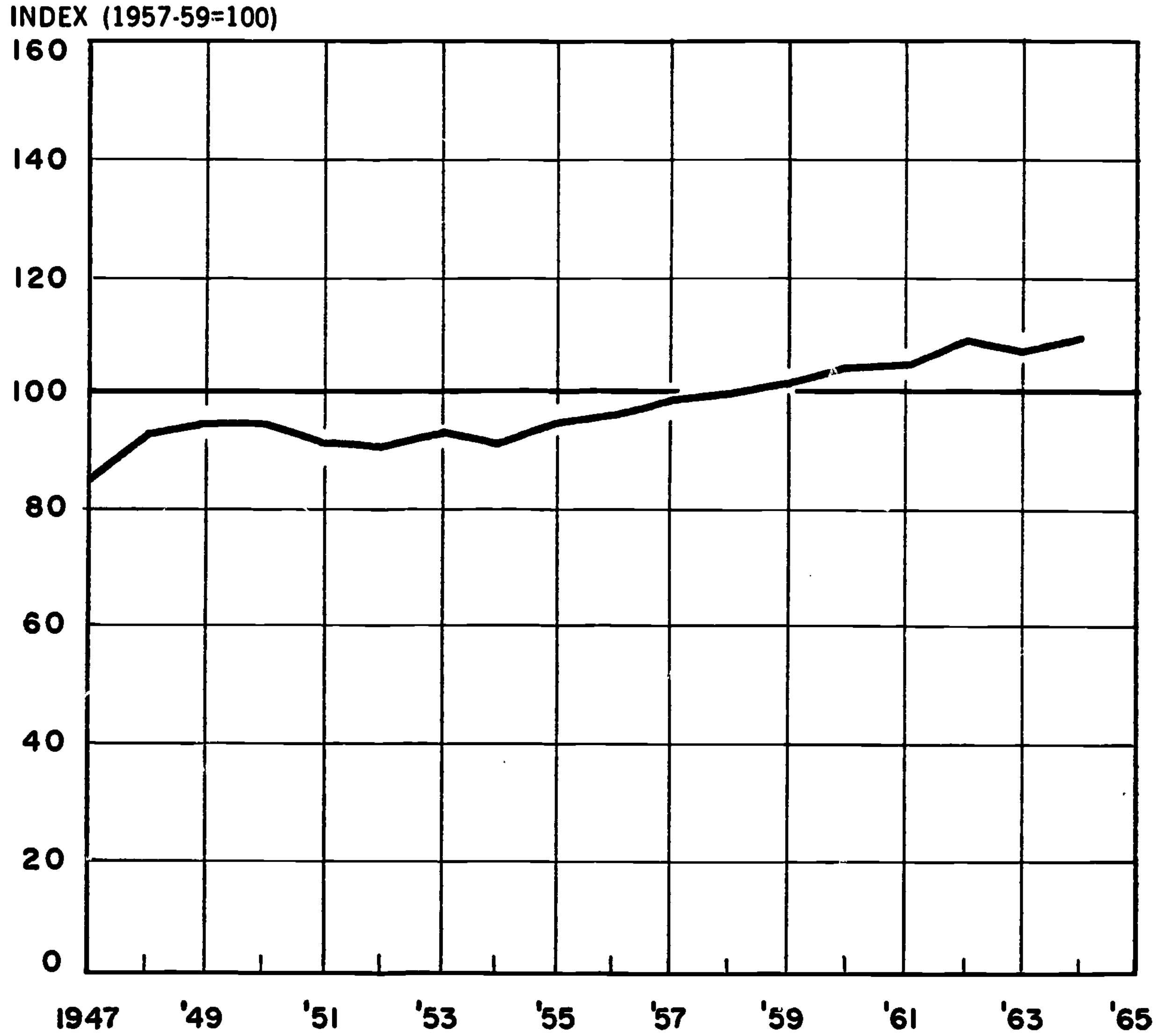
[73] Separate data on employment of salaried workers and self-employed workers are not available for the years prior to 1957.

needed to analyze the vast amounts of data furnished by data-processing equipment and to provide assistance to top policymaking officials. However, employment requirements for other types of managers and officials, such as advertising workers and public relations workers, will not be as directly affected by technological developments.

EMPLOYMENT OF MANAGERS, OFFICIALS, AND PROPRIETORS

(Except Farm), 1947-64

Employment (in 000's)	
1947	5,795
1948	6,344
1949	6,433
1950	6,429
1951	6,220
1952	6,182
1953	6,396
1954	6,201
1955	6,450
1956	6,552
1957	6,703
1958	6,785
1959	6,935
1960	7,067
1961	7,119
1962	7,408
1963	7,293
1964	7,452



Source: Bureau of Labor Statistics

Clerical and Kindred Workers

Employment Trends

Employment of clerical and kindred workers increased almost steadily between 1947 and 1964, rising from 7.2 million to almost 10.7 million, or 48 percent. This rapid increase in employment of clerical workers reflects not only the growth of the economy, but also growth in size and complexity of modern business organizations and government.

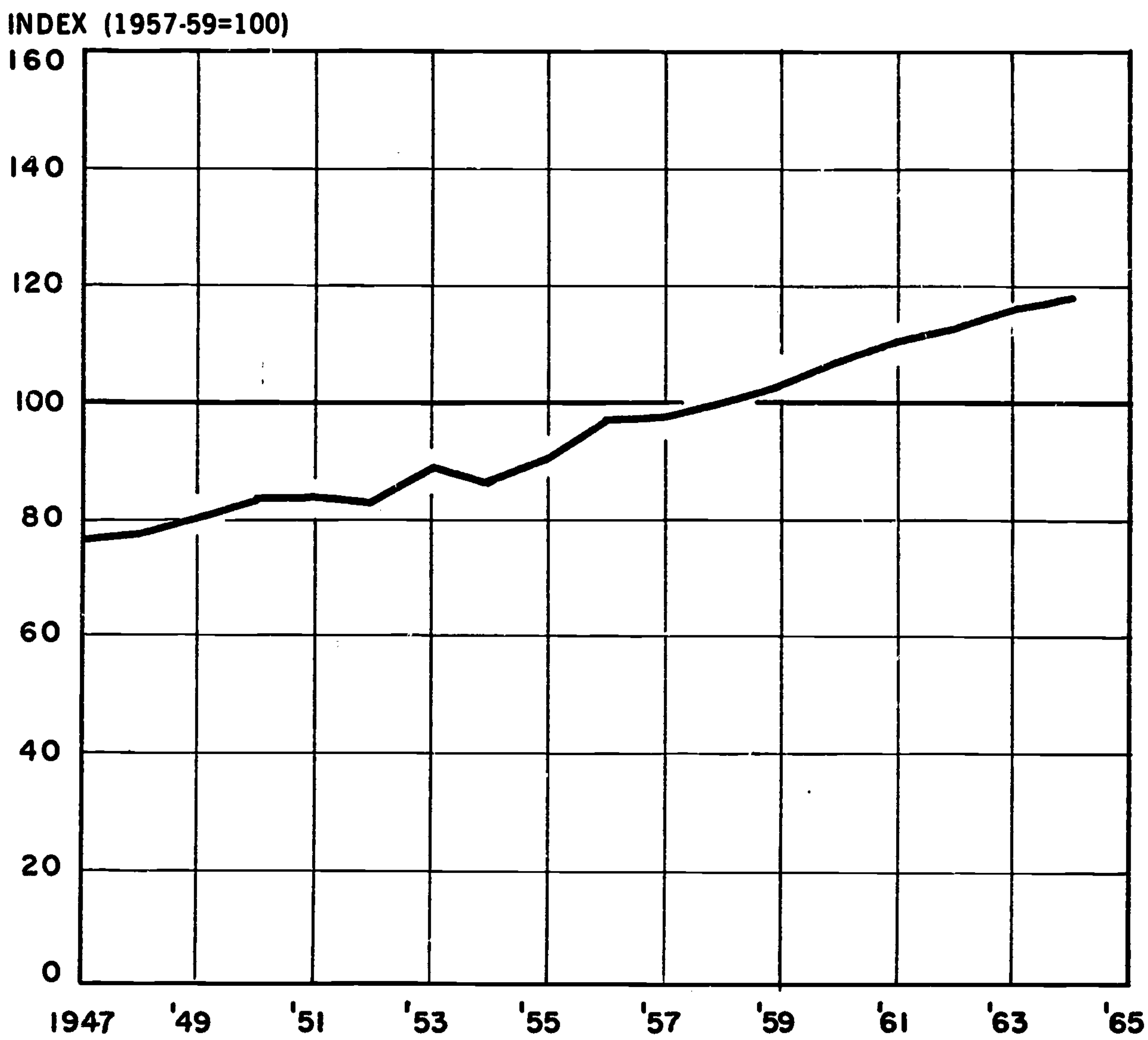
The rapid increase in amount of communications conducted through mail, telephone, and telegraph has also brought about a need for more clerical workers.

Clerical and kindred workers comprise the largest group of white-collar workers. More than 50 percent of all clerical and kindred workers are employed in manufacturing, wholesale and retail trade, and public administration. Large numbers also are employed in insurance companies, finance and real estate firms, educational institutions, and professional service organizations.

Employment requirements for clerical and kindred workers are expected to increase by more than one-third during the 1964–75 period, rising from 10.7 million to 14.6 million. Many new positions are expected to open up as the industries employing large numbers of clerical workers—such as banks and insurance companies, wholesale and retail trade establishments, manufacturing firms and government offices—continue to expand. The trend in retail stores toward transferring to clerical workers functions that were formerly performed by sales personnel will tend to increase the employment requirements for clerical workers. Furthermore, the continued increase in size and complexity of modern business organizations will help to increase the demand for clerical workers.

Employment (in 000's)	
1947	7,200
1948	7,438
1949	7,438
1950	7,632
1951	7,655
1952	8,122
1953	7,991
1954	8,168
1955	8,367
1956	8,838
1957	9,152
1958	9,137
1959	9,326
1960	9,783
1961	9,861
1962	10,107
1963	10,270
1964	10,667

EMPLOYMENT OF CLERICAL AND KINDRED WORKERS, 1947-64



Source: Bureau of Labor Statistics.

Effects of Technological Developments on Future Employment

Technological developments are expected to limit growth in employment requirements for clerical workers. The use of electronic computers, bookkeeping and calculating machines, and other mechanical devices for the purpose of processing routine and repetitive work is expected to result in substantial reductions in the number of clerks employed in routine jobs such as filing, sorting bank checks, making up payrolls, keeping track of inventories, and billing customers. On the other hand, the laborsaving advantages of these innovations will be offset to some extent by growing requirements for machine operators.

Growth in the requirements for secretaries, receptionists, and other clerical workers whose duties require initiative, judgment, and contact with the public is not expected to be significantly affected by technological innovations.

The following statements describe the employment trends and outlook for selected occupations in the clerical and kindred worker occupational groups: stenographers, secretaries, and typists; bookkeeping workers; and office machine operators.

Bookkeeping Workers

Employment Trends

Employment of bookkeeping workers increased from about 725,000 in 1950 to an estimated 1.1 million in 1964, or by 55 percent. This increase resulted primarily from expansion of economic activity and growth in the complexity of modern business, which tended to increase bookkeeping activity.

Bookkeeping workers are found in all industries. About 25 percent were employed by retail establishments and almost 20 percent by manufacturing firms in 1964. Banking and audit agencies employed more than 12 percent of the total, and wholesale trade establishments, over 10 percent.

Over the next decade, employment requirements for bookkeeping workers are expected to increase more slowly than they did during the 1950–64 period, primarily as a result of the increasing use of laborsaving technological innovations. Nevertheless, by 1975, employment needs for these workers may reach 1.4 million, 25 percent above the number employed in 1964. The increasing use of laborsaving technological innovations will limit the requirements for workers performing the more routine bookkeeping tasks, but there will continue to be many opportunities for bookkeepers capable of assuming responsibility for a full set of books.

Effects of Technological Developments on Future Employment

The increasing use of automatic data-processing and other mechanized bookkeeping operations is expected to limit growth in employment requirements for bookkeeping workers. Many types of machines, including posting machines, punchcard machines, and electronic computers, can process accounting and bookkeeping data more accurately, rapidly, and cheaply than it can be done manually. Electronic data-processing machines are expected to be used by more and more establishments for accounting and bookkeeping work, although the application of such equipment will remain far from universal. The feasibility of mechanizing an accounting function depends upon the cost saving, speed, or accuracy of a machine as compared with conventional methods, and many companies probably will not have the capital or volume of work necessary for automation. Furthermore, some firms will continue to combine electronic data-processing equipment with conventional equipment in their accounting operations. Even in companies that install electronic data-processing equipment, bookkeepers who did routine clerical posting before the machines were installed are not expected to be displaced to any great extent, since the bookkeeping demands of many firms will continue to grow, creating an increasing need for workers to prepare the inputs for the equipment and to prepare the additional reports made possible by using this equipment.

Electronic data-processing equipment is expected to be applied to an increasing number of recordkeeping functions in the decade ahead. For example, in banks the use of data-processing systems to sort checks by reading magnetized numbers, to credit individual accounts with deposits, and to subtract withdrawals is expected to expand sharply. In warehousing, computers are expected to be used increasingly to prepare daily inventory reports. Current developments also point to the increasing use of independent computer centers that offer data-processing services to the business community in general. Also, the size and cost of data-processing units are expected to be reduced, thus putting them within reach of small firms.

Office Machine Operators

Employment Trends

Employment of office machine operators (excluding typists) increased from an estimated 142,000 in 1950 to about 420,000 in 1964. Although the growing use of electronic computers limited the growth in requirements for operators of conventional office machines, it resulted in a rapid increase in the employment of operators of computers and auxiliary equipment. The major reason for the employment growth was a tremendous increase in the paperwork requirements of an expanding economy and growth in the size and complexity of modern business.

Office machine operators are employed mainly in firms with sizable recordkeeping requirements. Roughly one-third of all office machine operators work for manufacturing companies. Other large groups work for banks and insurance companies, government agencies, wholesale and retail firms, and transportation and public utility companies. Some office machine operators are employed in "service centers," agencies that contract to handle such tasks as preparing monthly bills and mailing circulars to lists of prospective customers.

Employment requirements for office machine operators are expected to more than double between 1964 and 1975, to about 900,000 workers. The projected increase in employment of office machine operators is based on continued growth of recordkeeping requirements in both the public and private sectors of the economy. Such large employers of office machine operators as manufacturing, insurance, and banking firms are expected to experience significant increases in paperwork volume, as both their volume of sales and number of customers continue to grow.

Effects of Technological Developments on Future Employment

Although employment requirements for office machine operators are expected to increase rapidly in the years ahead, technological developments are expected to limit growth in employment requirements for operators of certain types of office machines. The spread of automated recordkeeping processes may displace some tabulating and billing machine operators, since electronic computers generally perform these functions more efficiently. In addition, as automatic reading devices become a more common component of computer systems, requirements for keypunch operators to prepare material for use in computers may be adversely affected.

As more sophisticated computer systems are introduced in the future, the number of computer and auxiliary equipment operators needed per machine may decline. However, the spread of computer service centers and increasing use of time sharing, which will enable many firms to gain access to automated recordkeeping procedures for the first time, along with the increased applications of computers to more varied functions, should result in a rapid overall increase in the employment of computer operating personnel.

Furthermore, advances in interoffice communications and electronic computer technology should enable many large private firms and government agencies to consolidate recordkeeping functions at a central location; reducing requirements for office machine operators in many small branch offices without a corresponding increase in requirements for such workers in the central offices.

Stenographers, Secretaries, and Typists

Employment Trends

Employment of stenographers, secretaries, and typists increased by more than two-thirds between 1950 and 1964, rising from nearly 1.6 million to about 2.7 million. Expansion of economic activity and growth in the complexity of modern business tended to increase the volume of paperwork and, thus, employment requirements for these workers.

Stenographers, secretaries, and typists represent the largest group of clerical and kindred workers. Workers in this field are employed by public and private organizations of every size and type. Particularly large numbers work in manufacturing firms, government agencies, schools and colleges, banks, and insurance companies.

Employment requirements for stenographers, secretaries, and typists are expected to increase by more than one-third during the 1964–75 period, rising from the 2.7 million employed in 1964 to approximately 3.7 million in 1975. This projected increase in requirements will result from the continued expansion of general economic activity and, in particular, the continued rapid expansion of those industries employing large numbers of clerical personnel, such as finance, insurance, real estate, and banking. Furthermore, as modern business organizations continue to grow in size and complexity, the volume of paperwork also is expected to expand.

Effects of Technological Developments on Future Employment

Technological developments are not expected to limit significantly growth in employment requirements for stenographers, secretaries, and typists as a group during the decade ahead. However, the increased use of duplicating machines, Flexowriters, dictating machines, and other mechanical equipment is expected to increase output per employee, particularly of workers who perform the more routine tasks.

Sales Workers

Employment Trends

Employment of sales workers increased nearly one-third between 1947 and 1964, rising from about 3.4 million to nearly 4.5 million. Increased sales of many products, owing to rapid population growth, new product development, business expansion, and rising income levels, was the major reason for increased employment of sales workers. Employment in some types of sales work increased much faster than in others. Among the large sales occupations that had particularly rapid growth are real estate salesmen, insurance agents, manufacturers' salesmen, and wholesale salesmen. The smaller sales occupations of demonstrator, stock and bond salesman, and house-to-house salesman also increased rapidly. Among the slowest growing sales occupations were retail sales workers; however, these workers remain the largest group of sales workers.

The sales worker occupational group represented slightly more than 6 percent of all employed persons in 1964. About one-fourth were part-time employees who worked less than a 35-hour week. Women accounted for almost 40 percent of all sales workers and were employed primarily in retail stores.

Employment requirements for sales workers are expected to rise by about thirty percent between 1964 and 1975, to about 5.8 million, a faster rate of growth than has occurred in recent years. Among the major factors that will contribute to this employment increase are growth of population and increases in disposable personal income, which will result in a rising demand for goods and services. In addition, employment prospects in a variety of sales occupations will be further enhanced by the expected increase in residential and commercial construction and urban renewal (real estate agents); continued extension of such laws as workman's compensation and automobile liability insurance (insurance salesmen); and the trend for stores in metropolitan areas to remain open longer (retail salespersons). However, in recent years, many stores, such as variety stores, large supermarkets, and department stores have replaced sales workers with self-service and checkout counters, and this trend is expected to continue, but at a slower rate than in recent years. In addition, vending machines are expected to provide an increasing variety of goods once handled by sales workers.

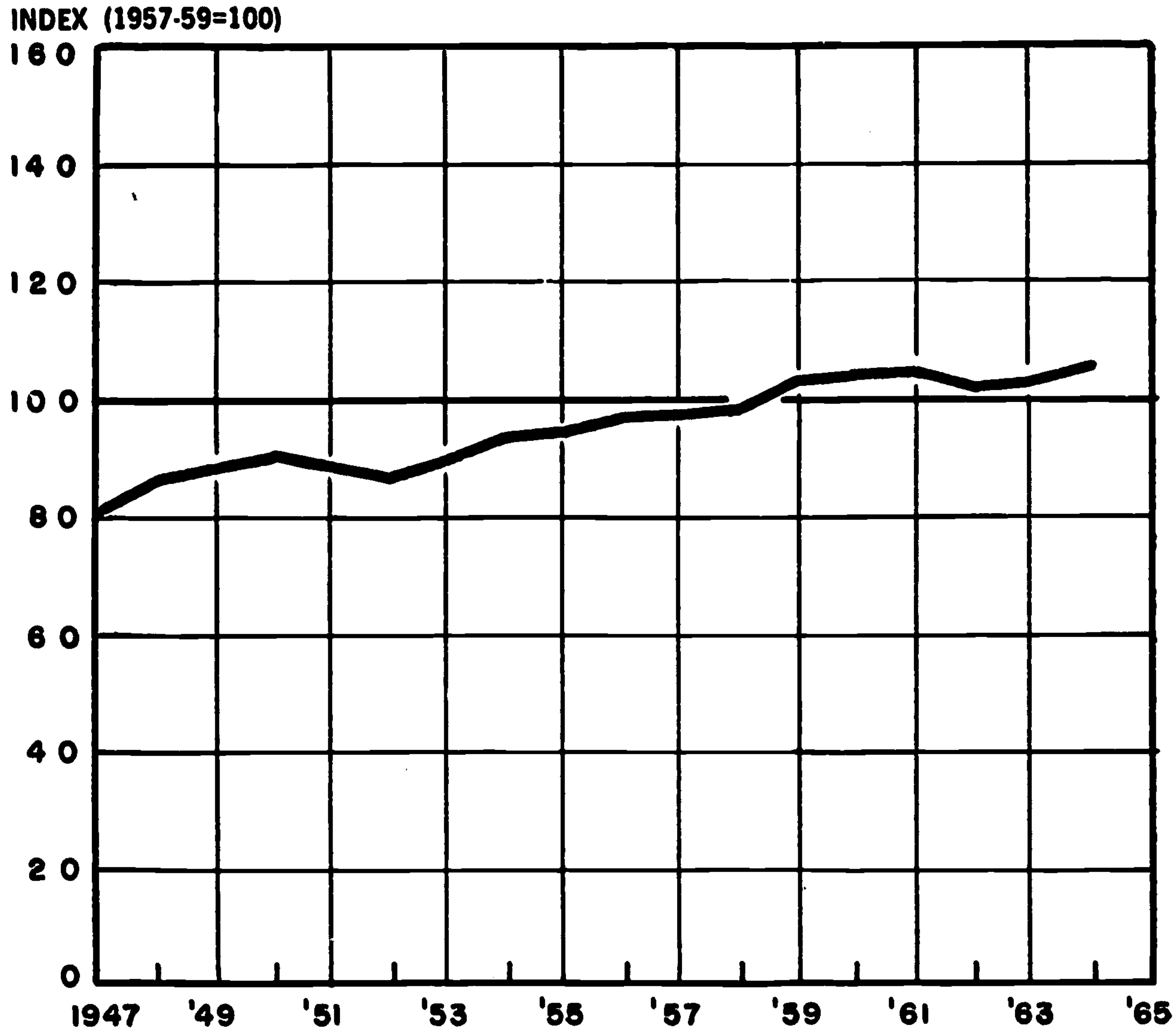
Effects of Technological Developments on Future Employment

The person-to-person contact usually required in most sales occupations, limits the impact of labor-saving technological innovations on employment requirements. For some sales occupations, technological innovations will primarily affect job duties.

The areas of sales work most susceptible to technological displacement are those for which little training is required (e.g., the activities of a salesgirl waiting on people in a variety store) and for which self-service procedures or vending devices may be substituted easily. The growth in employment requirements for salesmen dealing in specialized or technical services and products could be limited somewhat through the widespread use of improved communications systems (including computerized information systems) between branch and home offices. Such systems would facilitate information retrieval for the salesman confronted with questions or problems concerning specialized equipment, thus allowing him more actual sales time.

EMPLOYMENT OF SALES WORKERS, 1947-1964

Year	Employment (in 000's)
1947	3,395
1948	3,641
1949	3,737
1950	3,822
1951	3,750
1952	3,674
1953	3,779
1954	3,934
1955	3,976
1956	4,111
1957	4,128
1958	4,173
1959	4,394
1960	4,401
1961	4,439
1962	4,346
1963	4,356
1964	4,456



Source: Bureau of Labor Statistics.

Craftsmen, Foremen, and Kindred Workers (Skilled Workers)

Employment Trends

Employment of craftsmen, foremen, and kindred workers rose from less than 7.8 million in 1947 to nearly 9 million in 1964, and an increase of approximately 15 percent. Employment increased relatively rapidly in the early years of the period, reaching 8.4 million in 1951, but during the 1951–62 period changed only slightly, fluctuating between 8.3 and 8.7 million. In 1963, however, employment increased sharply to 8.9 million and in 1964, the nearly 9 million craftsmen represented the highest number ever employed in the United States.

More than half of all skilled workers were employed in two occupational groups in 1964—building trades (29 percent) and mechanics and repairmen (25 percent). There were more than 800,000 carpenters and about 750,000 automotive mechanics. Other skilled occupations, that had over 100,000 workers each, included electrician, painter, machinist, plumber and pipefitter, stationary engineer, operating engineer, bricklayer, compositor and typesetter, appliance serviceman, baker, and industrial machinery repairman. Many skilled occupations, however, had fewer than 20,000 workers each; for example, electrotyper, blacksmith, and glazier.

Although skilled workers are employed in almost every division of industry, more than half are employed in manufacturing and construction. More than three-fourths of all craftsmen work for private employers; others are self-employed or work for Federal, State, or local governments. The building trades, as a group, have a fairly large percentage of self-employed workers.

Employment trends during the post-World War II period varied sharply among the individual skilled occupations. For example, although construction activity increased during this period, employment of carpenters declined slightly, primarily as a result of growing use of prefabricated building components and the increasing efficiency of tools and equipment. In many railroad occupations, such as locomotive engineers, firemen, and railroad and car shop mechanics and inspectors, employment decreased significantly because of the decline in railroad traffic (particularly passenger traffic) and the introduction of laborsaving technological innovations such as the diesel-electric locomotive, welded rails, automatic car-weighing devices, and specialized maintenance equipment. Furriers, a very specialized occupation, suffered a sharp decline (70 percent) as the demand for natural furs fell drastically.

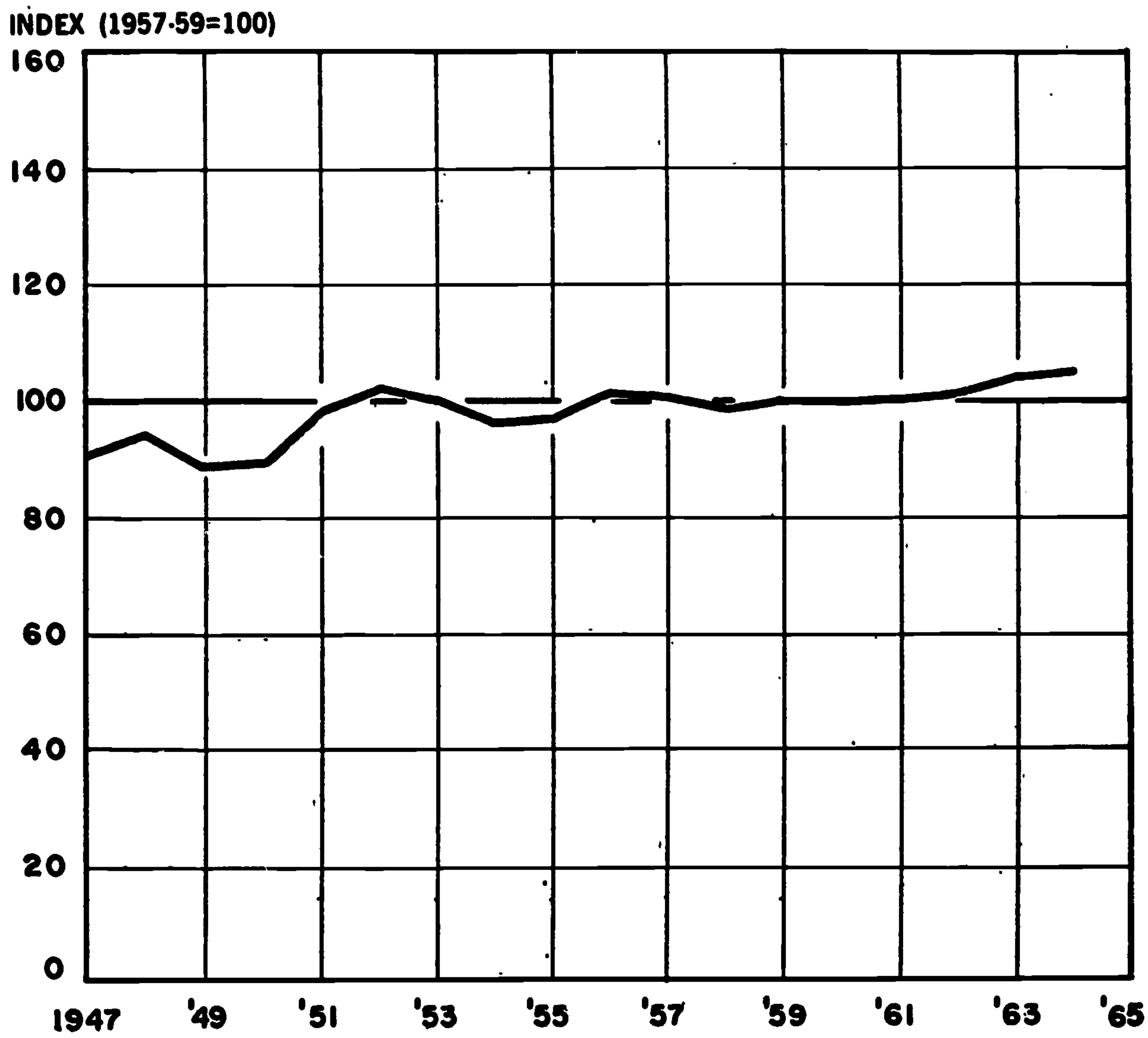
Many skilled occupations, on the other hand, increased in numbers during the postwar period. For instance, rapid increases in highway construction and the use of large, powerful excavating and grading road machinery resulted in a 55-percent increase in the number of operating engineers during the 1950–60 period. Increases in construction activity, including roads, buildings, and repairs, also resulted in significant employment gains for cement and concrete finishers (38 percent), construction foremen (65 percent), construction inspectors (85 percent), and structural metal workers (18 percent). Significant employment gains also were recorded for airplane mechanics and repairmen (62 percent), manufacturing foremen (46 percent), and tool and die makers (20 percent), primarily because of increasing business activity.

Employment requirements for craftsmen, foremen, and kindred workers are expected to rise by about one-fourth between 1964 and 1975, increasing from 9 million to 11.4 million. Industrial growth and increasing business activity are the major factors expected to increase the need for skilled workers.

As in the past, rates of employment growth will differ considerably among the skilled occupations. Employment of mechanics and repairmen should continue to grow more rapidly than the skilled work force as a whole. For example, industry will need increasing numbers of craftsmen to repair and maintain the automatic conveyor systems, sensing and measuring devices, and other instrumented equipment, which have become such integral parts of the modern industrial production process. A growing stock of household appliances also should increase the need for mechanics and repairmen. The number of skilled workers in the building trades and in the major skilled machining occupations are expected to increase at a slower rate than mechanics and repairmen, as technological laborsaving innovations are expected to offset the rising demand for construction and machining work. On the other hand, employment in the printing trades, one of the largest groups of skilled

EMPLOYMENT OF CRAFTSMEN, FOREMEN, AND KINDRED WORKERS, 1947-1964

Employment (in 000's)	
1947	7,754
1948	8,119
1949	7,625
1950	7,670
1951	8,434
1952	8,743
1953	8,588
1954	8,311
1955	8,328
1956	8,693
1957	8,664
1958	8,469
1959	8,561
1960	8,560
1961	8,623
1962	8,678
1963	8,925
1964	8,986



Source: Bureau of Labor Statistics.

workers, is expected to show little or no change over the next decade as laborsaving machinery continues to increase output per worker.

Effects of Technological Developments on Future Employment

Technological developments are expected to affect some skilled occupations favorably and affect others adversely. Technological innovations are expected to increase employment requirements for mechanics and repairmen, as greater numbers of skilled workers will be needed to install, maintain, and repair the growing volume of complex equipment that will be used by industry, government agencies, and private households.

Technological developments, on the other hand, are expected to limit the increase in requirements for skilled occupations in the building trades. As more building components such as wall panels, door frames, gables, and precast concrete trusses are prepared offsite, requirements will be reduced for carpenters and structural metal workers. Similarly, the growing use of plastic materials such as plastic pipes, polyfoam insulation, and plastic shells may reduce requirements for skilled workers such as plumbers and pipefitters, and brickmasons.

Although machining occupations are expected to rise slightly during the decade ahead, it is anticipated that increasing use of numerically controlled machines will limit employment growth of these skilled occupations.

Some skilled occupations are expected to decline during the next decade as a result of greater use of technological laborsaving devices. For example in the printing industry, some electrotypers and stereotypers are expected to be displaced by the growing use of more highly mechanized platecasting equipment. Similarly, the growing use of electronic testing and measuring devices in electronics manufacturing is expected to reduce the numbers of skilled inspectors and testers.

Airplane Mechanics[74]

Employment Trends

Employment of civilian airplane mechanics increased from an estimated 50,000 in 1950 to about 95,000 in 1964, a growth of 90 percent. Airplane mechanics employed by the scheduled airlines, which make up the largest single group in this occupation, increased by about 70 percent during this period, while those in other types of employment—nonscheduled airlines, general aviation and government—doubled. The rapid growth in employment of airplane mechanics during the 1950's and early 1960's was chiefly the result of dramatic increases in civil flying activity and in the number of registered aircraft. Over the 1954–64 decade, the total number of active registered aircraft on record with the Federal Aviation Agency increased from nearly 56,000 to more than 87,000, a rise of over 55 percent. In addition, the increase in size and complexity of many of the aircraft resulted in increased amounts of maintenance, checking, and overhaul time. Furthermore, the new generation of supersonic military aircraft resulted in an increased need for civilian mechanics to maintain them.

Over one-third of all airplane mechanics are employed by certificated (scheduled and nonscheduled) airlines. About a fourth are employed by the military and other agencies of the Federal Government. The remaining mechanics are employed in general aviation, primarily by certificated repair stations.

Employment requirements for airplane mechanics are expected to increase to about 115,000 workers by 1975, nearly 20 percent above 1964. This projected increase will result primarily from the anticipated growth in civil flying activities, including a rapid rise in the number of aircraft in use. Nearly all of the projected growth in civilian aircraft is expected to occur in general aviation, especially among business aircraft users and small commercial operators. The major stimulus for this increase in the number of general aviation aircraft, and the consequent need for mechanics to maintain them, will result from the rising demand for fast and dependable, yet flexible air transportation services. On the other hand, although scheduled airline traffic, both passenger and cargo, is projected to increase very rapidly in the next decade, the number of aircraft required to handle this traffic is expected to remain fairly constant due to the increasing replacement of piston-engine planes by faster, higher capacity jet planes. Since the employment of airplane mechanics depends primarily on the number of aircraft in service, the number of mechanics employed by the scheduled airlines is expected to remain fairly stable over the next decade.

Effects of Technological Developments on Future Employment

Employment requirements for airplane mechanics are not expected to increase as fast as civil flying activities in the years ahead, due to technological improvements that will limit the increase in the total number of aircraft in operation and improve the efficiency and speed of aircraft maintenance work.

The continued replacement of piston with turbine-powered aircraft will allow the scheduled airlines to absorb the future demand for air transportation with little or no increase in fleet size or mechanic employment. Although jet airliners are used more intensively than their predecessors, they involve fewer powerplant mechanics due to the greater simplicity of the jet over the piston engine, and reduced overhaul requirements. This decline in the relative importance of powerplant mechanics will be offset, however, by increased requirements for airframe mechanics to service the growing array of complex aircraft control systems incorporated in modern jet transports.

Although technological developments may also limit employment opportunities for mechanics in firms providing general aviation services, the overall expansion in general aviation aircraft projected for the next decade will result in a net increase in mechanic employment. Technological advances in general aviation, particularly in business flying and air taxi, have resulted in more efficient, higher capacity turbine-powered aircraft and multiengine piston aircraft. In addition, general aviation aircraft are being equipped with sophisticated aids to simplify flying and increase safety. The major effect of these developments will be to increase the skill requirements among general aviation aircraft mechanics.

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[74] This discussion excludes production workers employed in the aircraft and parts manufacturing industry.

Automotive Mechanics

Employment Trends

Employment of automotive mechanics increased from 650,000 in 1950 to an estimated 760,000 in 1964 in response to the rising demand for motor vehicle repairs. The number of motor vehicles in use, the primary determinant of the demand for repairs, increased from about 49 million to an estimated 86 million during the same period.[75] In addition to increasing in number, motor vehicles increased in complexity during the late 1950's and early 1960's as a result of the growing popularity of items such as automatic transmissions, power steering, and air-conditioning. The trend toward more complex motor vehicles increased the demand for repairs.

About 40 percent of all automotive mechanics are employed by independent auto repair shops and 25 percent by auto and truck dealers. Other major employers of automotive mechanics are gasoline service stations, motor vehicle manufacturers, and operators of large fleets of trucks or buses.

Employment requirements for automotive mechanics are expected to rise by more than 17 percent between 1964 and 1975, to about 880,000. The projected increase in employment requirements is based on an anticipated substantial increase in the number of motor vehicles in use. Registrations of motor vehicles in the United States are expected to increase by more than one-fourth in the next 10 years because of factors such as population growth, new household formations, increased consumer purchasing power, more multi-car ownership, and increases in the transportation of freight by trucks. The increase in the number of motor vehicles, coupled with their growing complexity, will increase the need for automotive mechanics. However, employment requirements are expected to increase slower than motor vehicle registrations because of increases in efficiency stemming from factors such as increased mechanic and repair shop specialization, greater emphasis on replacement rather than repair of parts, and laborsaving technology.

[75] *Automobile Facts and Figures, 1965,* Automobile Manufacturing Association, p. 18.

Effects of Technological Developments on Future Employment

Although technological developments are not expected to have a substantial impact on employment requirements for automotive mechanics, the greater use of laborsaving tools and test-equipment will result in a moderate reduction in unit labor requirements.

Power tools, such as pneumatic wrenches and cutting tools, and special purpose tools such as transmission jacks and differential jacks should reduce the amount of time it takes a mechanic to disassemble and assemble motor vehicle components.

Test equipment such as distributor-testers, engine analyzers, and dynamometers should increase efficiency by reducing the amount of time it takes a mechanic to diagnose malfunctions and check the quality of repairs. A recent development is the application of dynamometers and other test equipment to production-line diagnosis of motor vehicle malfunctions in repair shops. In such shops, diagnosticians who are skilled in operating test equipment determine needed repairs and route vehicles to mechanics who are specialists in making particular kinds of repairs. Although few shops presently use production-line diagnosis, the number may increase significantly during the next decade. As a result, the employment of diagnosticians and mechanic specialists may increase faster than the employment of all-round mechanics.

Gains in efficiency resulting from laborsaving devices will be offset to some extent by increased maintenance requirements stemming from the trend toward greater complexity in motor vehicles. During the next decade, a growing proportion of the automobiles in use are expected to be equipped with air-conditioners, power steering, crankcase and exhaust emission control devices, and other items which add to maintenance requirements, thus increasing the need for mechanics. However, increased complexity will not always be accompanied by greater maintenance requirements. For example, a slight reduction in unit maintenance requirements for trucks will probably result from the more widespread use of diesel engines. Diesels are more complex mechanisms than the gasoline engines they replace, but generally require less maintenance.

Bakers

Employment Trends

Total employment of bakers decreased from about 115,000 in 1950 to about 105,000 in 1964, a decline of approximately 9 percent. Factors that contributed to the decrease in employment requirements in this occupation included the increasing mechanization of bakery production processes and the decrease in total number of establishments in the baking industry.[76]

A substantial proportion of skilled bakers, nearly 7 of every 10, were estimated to be employed in the bakery industry in 1964. Nearly 1 of every 4 worked in retail bakeries that produce their own baked goods. The remainder were employed in establishments such as schools, hospitals, hotels, and restaurants.

Employment requirements for bakers are expected to decrease about 10 percent between 1964 and 1975 primarily because of reduced manpower requirements in industrial bakeries. The projected decrease is based on an anticipated rise in the use of highly mechanized processing equipment and increasing use of freezing processes. Since these technological developments are best utilized in large establishments, and the bakery industry is characterized by a large number of small establishments, it is anticipated that the total number of establishments also will continue to decrease. For example, between 1958 and 1963, the total number of industrial bakeries producing bread and related products declined by approximately 15 percent.

[76] In contrast to the decline in establishments in the baking industry, bake shops, classified in retail trade, which employ a substantial number of bakers, remained relatively stable between 1950 and 1964.

Effects of Technological Developments on Future Employment

Employment requirements for skilled bakers are expected to continue to be adversely affected by laborsaving technological developments that will make it possible to increase output with fewer workers.

The automation of bread production through the continuous mix process virtually eliminates manual operations in the production of this product and increases production capacity. The continuous mix process involves the use of mechanical and electronic devices that mix the ingredients, knead the dough and extrude it into loaves or rolls, carry it through proofing chambers and ovens to the depanning equipment, and to the automatic wrapping machine.

Employment requirements for bakers producing such specialty products as French bread, club rolls, etc., will probably be reduced because of the increasing use of mechanical production devices that require a minimum of direct labor. Using new equipment, the production of these specialty breads can be doubled and tripled with half the number of workers formerly required.

The growing use of freezing processes makes it possible to increase production without danger of spoilage. This makes it possible to eliminate second and third shifts. The use of freezing processes also increases the distribution area and contributes to the decrease in the number of establishments necessary to serve an area.

Business Machine Servicemen

Employment Trends

It is estimated that employment of business machine servicemen more than doubled during the post-World War II period, reaching about 70,000 in 1964. The growing employment of servicemen has been due to increasing use of many types of office machines to do all kinds of clerical work in our expanding commercial and industrial establishments. Additional business machine servicemen were employed to maintain and service increasing numbers of office machines used for correspondence, for recording and processing transactions, and for duplicating and mailing information. Equipment used for these purposes includes typewriters, adding and calculating machines, cash registers, electronic computers and other data-processing devices, dictating and transcribing machines, and mailing and duplicating equipment. In addition to greater numbers of machines, many technical changes in long-established types of business machines have increased the need for servicemen. For example, electrically driven mechanical equipment (which requires more maintenance), including electric typewriters and adding machines, is rapidly taking the place of nonelectrical mechanical machines.

In 1965, there were an estimated 25,000 typewriter servicemen, 16,000 electronic data-processing equipment servicemen, 2,000 dictating machine servicemen, 5,000 duplicating and copying machine servicemen, and 5,000 calculating machine servicemen. In recent years, the number of dictating machine servicemen, duplicating and copying machine servicemen, and data-processing equipment servicemen has grown fastest and calculating machine servicemen slowest.

Employment of business machine servicemen depends on machine population, intensity of machine use, and the complexity of the various types of machines and their service requirements.

Employment requirements for business machine servicemen are expected to rise by fifty percent between 1964 and 1975, reaching about 105,000. Those business machine service occupations expected to grow fastest are typewriter servicemen, adding machine servicemen, data-processing equipment servicemen, and duplicating and copying machine servicemen. Those occupations in which employment is expected to grow less rapidly are calculator servicemen, servicemen of postage and mailing equipment, and cash register servicemen.

Effects of Technological Developments on Future Employment

Continued technological improvements in office equipment are expected to stimulate the demand for business machines and thereby increase overall requirements for business machine servicemen. The development of new types of business machines and the technological improvements in existing lines of equipment can be expected not only to increase the demand for skilled servicemen but also to affect changing skill requirements in existing positions.

The widespread innovations in business equipment will affect employment and job requirements of servicemen in many branches of the occupation. For example, the demand created by the recent introduction of a broad range of electrostatic process copiers and the improvements in other copying and duplicating processes will increase employment and raise skill requirements for servicemen in this field. The development of new microfilmed information storage systems with rapid retrieval and automatic print-out features will require servicemen with a knowledge of photographic processes and skills to maintain electromechanical assembly and control devices. The broadening application of computer technology to business accounting and control functions (E.D.P.) in virtually every industry will increase employment requirements for service personnel with electronic, as well as electromechanical, knowledge and skills.

Technological innovations also are affecting considerable change in the servicing of equipment long established for office and business use. The continuing replacement of manual with electric typewriters will force many typewriter servicemen to acquire new skills or yield advancement opportunities to younger men trained to service this electromechanical equipment. The growing use of more complex cash registers; electronic calculators and accounting machines; and integrated postage, addressing, folding, and mailing machines all tend to increase employment requirements but place greater emphasis on more highly trained servicemen.

Tempering this optimistic outlook are developments which may dampen the overall upward surge in employment requirements. The trend to solid state and microcircuit electronic components, and to plug-in modular units and printed circuits will reduce failures and simplify replacement in electronic computers, accounting machines, and dictating and transcribing equipment. In addition, improved tools and testing devices for diagnosing machine breakdowns may reduce time and effort required to service business machines.

Carpenters (Construction Industry)

Employment Trends

Carpenters in the construction industry declined from about 839,000 in 1950 to 640,000 in 1964, but remained the largest group of skilled workers in the construction industry. This decline can be attributed in part to the growing use of prefabricated building components and the increasing efficiency of tools and equipment, both of which increased the value of construction put in place per worker.

Employment requirements for carpenters are expected to rise to about 670,000 in 1975. The projected increase in requirements for carpenters is based on an anticipated rapid increase in construction activity, particularly residential building where a high proportion of the labor requirements are for carpenters.[77] The factors that are expected to stimulate construction activity include large increases in population and in the number of households, higher levels of personal and corporate income, rising expenditures for new industrial and commercial facilities, a continuing shift of families from cities to the suburbs, and increases in government expenditures for highways and schools.

Effects of Technological Developments on Future Employment

The increase in carpenter employment through the mid-1970's will not be as great in construction

[77] Almost 85 percent of all on-site labor on single family houses is performed by carpenters, according to a Bureau of Labor Statistics' study.

activity, because of technological developments that will increase the real value of construction put in place per carpenter, or reduce the demand for carpentry work. For example, an increase is expected in the use of building components that are prepared off site. These components, which include wall panels, door frames, windows and frames, trusses, gables, roofs, floors, partitions, and stairs, are designed for easy and speedy installation. Walls and partitions are lifted into place in one operation, sometimes by workers other than carpenters. Beams and, in some instances, roof assemblies are lifted into place by cranes. With the standardization of prefabricated components, the use of such materials will increase further.

More widespread use of improved tools and equipment will increase the efficiency of carpenters. Such products include new types of nails that have improved holding properties; hence, fewer nails and less hammering are required. Power tools in use include stud drivers, screw drivers, sanders, saws, staplers, and nailing machines. One relatively new power tool can drill and nail in one operation. New types of scaffolding are in use that are easier to erect, safer to use, and easier to adapt to varying construction situations.

Employment of carpenters also will be affected by the increased use of construction materials and techniques that reduce the amount of carpentry work required in building construction. For example, steel framing, already used in many commercial buildings may be used increasingly in houses. When houses are framed with steel, the use of curtain wall panels, which can be quickly fastened into place, is possible. Curtain wall panels may reduce the need for carpenters because they are available in nonwood materials, such as glass, aluminum, and porcelain-coated steel, which can be installed by craftsmen other than carpenters. In addition, the use of plastics in building construction is in its infancy, but plastic siding, curtain walls, partitions, roofing, ornamental screening, and insulation materials are already being used. Under development are foam plastic roofs and even entire houses of plastic that can be constructed on site. Also, the use of strong adhesives in place of conventional fasteners is expected to increase, reducing the time needed to join pieces of wood and other materials.

Cement and Concrete Finishers and Terrazzo Workers (Construction Industry)

Employment Trends

Employment of cement and concrete finishers and terrazzo workers in the construction industry totaled approximately 54,000 in 1964, more than two-thirds higher than estimated employment in 1950. This rapid increase resulted primarily from an increase in construction activity and a growing use of concrete and concrete products.

Manpower requirements for cement and concrete finishers are expected to be nearly 75,000 in 1975, almost two-fifths higher than in 1964. Requirements are expected to rise because of an anticipated rapid increase in construction activity, especially highway, industrial, and commercial construction.

The increase in construction activity will continue to be accompanied by a growing use of concrete products, especially prestressed concrete and lightweight concrete wall panels. Prestressed concrete makes possible wide spans where column-free construction is desired. The use of prestressed concrete allows artistic yet functional designs. Fire- and weather-resistant lightweight concrete wall panels, available in different finishes, colors, and designs are being used increasingly in nonload-bearing walls. These panels can be speedily fastened into place, in some instances allowing the building to be dismantled and re-erected elsewhere. The use of concrete and concrete products has expanded to include thin-shell dome roofs, ornamental grillwork, and slab and arch roofs in residential buildings; and girders, columns, piles, and beams for bridges. In addition, concrete can now be placed during cold weather by using heated, temporary shelters made of sheet plastics.

Requirements for terrazzo workers are expected to increase very rapidly through the mid-1970's, especially in Florida and California and other warm regions of the country, where concrete flooring is often necessary to prevent insect damage. Because terrazzo is durable and attractive, the number of terrazzo installations is expected to continue to increase rapidly. Growth of the trade also will be stimulated by the use of new materials, especially epoxy and latex terrazzo, which are lighter and take less space than cement-based terrazzo and can be used on the upper floors of multistoried buildings. A small number of skilled terrazzo workers have been recruited from abroad to meet shortages of such craftsmen in some areas.

Effects of Technological Developments on Future Employment

The more widespread use of relatively new technological developments is expected to limit the growth of manpower requirements in this occupation. For example, many concrete products can be precast away from the construction site and these products usually do not require finishing. Concrete slabs for floors, walls, and roofs can be processed at ground level and raised into place by synchronized hydraulic jacks or cranes. For certain jobs, concrete can be applied pneumatically through hoses. In addition, glass-fiber-reinforced plastic forms provide a smooth concrete surface, thus eliminating rubbing and patching work. Steel and plastic-covered wood forms are now available that can be reused many times. Adhesives are available that reduce the need for bolts and other types of fasteners. Output per worker has been increased by the introduction in recent years of new machines, including powered concrete conveyors and wheelbarrows, portable powered screeds, electric concrete vibrators, joint forming machines, powered concrete cutting saws, and cement-finishing machines.

Compositors and Typesetters

Employment Trends

Employment of compositors and typesetters increased slightly between 1950 and 1964—from about 173,000 to about 180,000, while production in the printing and publishing industry rose by more than 50 percent. Employment growth was limited by the increasing use of technological innovations in typesetting equipment and processes.

Compositors and typesetters make up the largest group of skilled printing craft workers. About four-fifths of all these craftsmen were employed in the printing industry in 1964. Others were employed in paper and allied products establishments; in wholesale and retail trade; in finance, insurance, and real estate; and in government. Despite significant increases in production, employment requirements for compositors and typesetters are expected to decline to about 155,000 workers in 1975, because of the increasing application of laborsaving devices.

Effects of Technological Developments on Future Employment

Several major technological developments are expected to affect the demand for compositors and typesetters during the 1964–75 decade. The increasing use of automatically operated typesetting equipment will make it possible to double and even triple the volume of type that can be set by each worker. A tape-operated typesetting machine can set up to four newspaper columns of type an hour, compared to one column an hour set on a manually operated machine. The recent application of electronic computers to the typesetting process will make it possible to set type even faster. Through the use of programed computers, typists who do not have to concentrate on spacing lines of copy or hyphenating words can perforate an unbroken stream of words and letters on the tapes. These tapes are fed into a computer that produces a second tape on which words have been automatically grouped to form a column of print with uniform right-hand margins. By consulting a "dictionary" stored in its memory unit, the computer can properly hyphenate words when necessary to fill out the lines. The computer also adds the code symbols to activate the typesetting machines. Because the tape perforating machines have keyboards similar to those of typewriters, typesetters who shift to this operation must have or acquire typing skills. However, with the addition of a computer to the typesetting process, typists can be substituted for typesetting operators, thus reducing the number of these skilled workers required.

Employment of compositors and typesetters also will be affected by more widespread use of photocomposition in place of metal type. In conventional typesetting and composition, lines of words are molded into blocks of metal. These blocks or "slugs," together with illustrative materials in the form of cuts or photoengravings, are arranged in frames to form pages. Arranging the metal type and illustrative materials is a time-consuming process, and one which requires knowledge of the use of gages and mitering equipment. In photocomposition, the metal type is replaced by strips of film of the printed matter that are developed and pasted on sheets of layout paper together with pictures or other illustrations. These sheets are photographed and metal engravings are made from the negatives for letterpress printing. The assembling of photocomposition materials is easier and faster than the assembling of metal type, and fewer workers are required to produce the same amount of composition. Although the use of photocomposition equipment requires some photographic skills, and some of the compositors working on phototypesetting materials must learn to operate cameras, the general skill level required is less than that needed to set up metal type. The most recent photocomposition equipment not only set lines of type, but also assembles complete pages of advertising copy, thus eliminating the need for the pasteup operation.

Electricians (Construction Industry)

Employment Trends

Estimated employment of electricians in the construction industry rose from about 112,000 in 1950 to approximately 162,000 in 1964, an increase of about 44 percent. In recent years, however, the rate of employment growth has slowed because of the increasing use of laborsaving technological innovations.

Employment requirements for electricians are expected to increase to approximately 200,000 in 1975, nearly one-fourth above the 1964 employment level. Requirements for electricians are expected to increase because of a rapid expansion in construction activity resulting primarily from rising population, family formations, and personal and corporate income. Increased requirements for electric outlets, switches, and wiring in homes are expected in order to accommodate the increasing use of appliances and air-conditioning systems. In addition, more extensive wiring systems will be needed for the installation of electronic data processing equipment and electrical control devices being used increasingly in commerce and industry. Also, the number of "all-electric" homes and the use of outdoor radiant heating and snow and ice-melting systems are expected to increase.

Effects of Technological Developments on Future Employment

Technological developments are expected to limit manpower requirements in this trade. A major development that is increasing output per worker is the prefabrication of electrical equipment. For example, conductors are now factory assembled into flexible armored cable, which is laid in cable trays at the construction site, thus eliminating the need to run conduit, and to pull conductors through it. Switchboxes and switchboards, which formerly had to be wired on site, now are preassembled at the factory. "Packaged" (preassembled and prewired) ceiling units that the electrician connects to the power source eliminate the need to wire the complete system and install the individual fixtures. In addition, the installation of "luminous" ceilings is increasing. The use of these ceilings reduces the need for individual feeders to fixtures; however, some additional work is required in installing louvres.

Improved tools and equipment being used increasingly by electricians include more efficient conduit benders; multiple spindle drills; cordless electric drills, saws, and other tools; and "kits" of splicing materials that have reduced the time needed to do field insulation of cable splices.

Excavating, Grading, and Road Machinery Operators (Construction Industry)

Employment Trends

Estimated employment of excavating, grading, and road machinery operators in the construction industry more than doubled between 1950 and 1964, reaching nearly 185,000. This rapid increase was spurred by increases in construction activity, especially in highway construction. In response to the demand for better methods to facilitate expansion of activity, many new types of excavating, grading, and road machinery were introduced during this period.

Manpower requirements for operators are expected to increase to approximately 265,000 in 1975, more than two-fifths above the 1964 level. The projected increase in requirements for these skilled workers is based on an anticipated rapid increase in construction activity, particularly highway construction. The need to maintain and repair the Nation's expanding system of highways also will increase requirements for these workers. In addition, the trend toward greater use of construction machinery is expected to continue. More specialized and complex machines, particularly those used in earth moving, as well as smaller machines suitable for small construction projects, are being developed and are expected to be used increasingly.

Effects of Technological Developments on Future Employment

Technological developments are expected to limit the growth in employment requirements for excavating, grading, and road machinery operators. The size, speed, mobility, and durability of construction equipment are being increased. For example, earth-moving machines now move many times the amount of material that could be moved by the largest machine in use a few years ago, but still require only one operator. Scrapers are in operation that can scoop up and carry from 50 to 150 cubic yards of dirt in one load. Redesign of equipment, including machinery components has reduced breakdowns and improved maintenance efficiency. Many of the new machines are equipped with automatic lubricating systems, power steering, power transmissions, rubber tires, and electronic and hydraulic controls, which make them easier to handle, more maneuverable, and faster than the older equipment.

In addition to improvements in conventional equipment, many types of machines developed in recent years are expected to gain widespread use in the future. An example of such a machine is the slip-form paver, which spreads, vibrates, forms, and finishes concrete paving in one continuous operation. The slip-form paver replaces at least four other machines formerly used in concrete paving. This machine, aided by highly efficient central mixing plants, promises to further increase the efficiency of highway paving operations. Another machine that has recently been developed to perform a special job is a pipelaying machine that digs the trenches, lowers the pipe, and fills the trench after the pipe is laid. Automatic controls also have become more widespread and are being used increasingly in road machinery. For example, the use of electronic grade controls on highway-paving equipment results in smoother pavements and a greater efficiency of the paving operation in general.

Although the increasing use of new and improved machines is expected to decrease unit labor requirements for skilled operators, the development of special-purpose machines designed to perform jobs for which machines are not now available, especially those designed specifically for use on smaller construction projects, is expected to stimulate employment requirements for these workers.

There will be greater requirements for heavy equipment mechanics to keep the expanding number of machines in good working order. However, the need for construction laborers will be reduced as machines are used increasingly to perform jobs now performed manually.

Machinists

Employment Trends

Employment of machinists[78] remained relatively stable between 1950 and 1960—at an estimated level of slightly below half a million. After 1960, employment declined somewhat, falling to about 480,000 in 1964. The decline in the employment of machinists occurred despite a substantial expansion in machining activity. For example, output increased by almost 88 percent in the machinery industry between 1950 and 1964.

Among the major factors that reduced requirements for machinists were the replacement of skilled machinists by less highly skilled machine operators, the use of automatic transfer equipment that reduced requirements for setup and layout men, increased power and speed of conventional machine tools, and the introduction of numerically controlled machine tools. In addition, advances in instrumentation and automatic inspecting equipment have tended to reduce the requirements for machinists employed as inspectors in metalworking industries.

Almost every factory using a substantial amount of machinery employs machinists to keep its mechanical equipment in operating order. Some machinists work in the production departments of metalworking establishments where large quantities of identical parts are produced; others work in job shops where a limited number of various products are made. Most machinists work in the machinery, electrical equipment, transportation equipment, fabricated metal products, and primary metals industries. Other industries employing substantial numbers of machinists are the railroad, chemical, food-processing, and textile industries.

Employment requirements for machinists are expected to increase slightly between 1964 and 1975, from an estimated 480,000 to about 500,000 workers. The anticipated increase in the use of numerically controlled machine tools and other new metal working methods should restrict employment requirements for machinists, despite an anticipated rapid growth in metalworking activities. Population expansion and increasing personal disposable income are expected to result in a rapid increase in purchases of consumer products such as automobiles, heating and air-conditioning units, and home appliances produced in metalworking industries. Expanding business and consumer demand should result in higher expenditures on new industrial plant capacity and stimulate orders for industrial machinery, machine tools, materials handling equipment, engines, instruments, and other products manufactured in the metalworking industries. In addition, expanded activity in the construction industry is expected to stimulate the demand for construction machinery.

[78] Machinists, as defined for the purpose of this report, include workers in a variety of related occupations. For example, job setters, machine adjustors, bench hands, instrument makers, layout men, maintenance machinists, and inspectors (machine shops) are classified under the broad heading of machinists.

Effects of Technological Developments on Future Employment

Employment requirements for machinists will be restricted by the expanding use of numerically controlled machine tools. Numerical control constitutes a key technological development in the evolution of machine tools. Previous changes largely involved improvements in speed, power, and specialization of machine tools. Numerical control of machine tools, on the other hand, is a technique of automatic machine operation by means of coded instructions provided by magnetic or paper tapes. It constitutes a technique for reducing unit labor requirements below those required by conventional machine tools.

Numerical control is expected to have different effects on various types of machinists. The use of numerically controlled machine tools significantly reduces tooling and setup time because of the substitution of tape controls for many conventional jigs and fixtures. This aspect of numerical control will reduce the requirements for machinists who are employed as job setters. Since numerical control results in more accurate machining, the time needed to inspect finished parts is reduced substantially, resulting in limited employment requirements for machinists employed as inspectors. The expanded use of numerical control also will limit the need for production machinists employed both in job shops and in machining departments of other metalworking establishments that manufacture a wide variety of different metal parts.

Employment of machinists also could be adversely affected by the increased use of computers and numerically controlled equipment in designing parts, eliminating some of the requirements for layout men (machinists), particularly in the automotive industry. Since some highly skilled machinists are employed in metalworking repair shops and research and development laboratories where numerical control is less likely to be used extensively, the impact of this technology on the employment of these machinists may be limited.

Numerical control also will tend to change, to some degree, the job content and skill requirements for some maintenance machinists. Numerically controlled equipment is composed of complex mechanical, hydraulic, and electronic systems. Depending on company practice, some maintenance machinists may be required to have an understanding of electronics in order to service both the machine tool and the control system.

Other new metal-removing processes are in use or under development that remove metal without the use of a cutting tool. The more important techniques include chemical machining, electrolytic machining, electrical discharge machining, and laser beam machining. However, since these techniques are now in their development stages or in limited use, their impact on employment requirements for machinists is not yet clear.

Painters (Construction Industry)

Employment Trends

Estimated employment of painters in the construction industry decreased by 15 percent between 1950 and 1964, from 335,000 to 285,000. Much of this decrease in employment was due to the increasing use of paints that required little or no mixing, and spray guns and rollers that permitted faster application of paints even by inexperienced workers. In addition, the growing use of aluminum and other building products that often require no painting adversely affected employment needs.

Employment requirements for painters are expected to rise by about 8 percent between 1964 and 1975, to about 305,000, reversing the 1950–64 employment trend. The expected increase in requirements for painters will result mainly from the increase in construction activity, including maintenance work. In addition, the development of paints that are heat, abrasion, and corrosion resistant should expand the market for paints and the demand for painters. Although technological innovations will continue to limit employment of painters, the major impact of some important developments including ready-mixed paints, rollers, and, to some extent, spray guns has already occurred.

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Effects of Technological Developments on Future Employment

Technological developments are expected to continue to limit manpower requirements in this trade. One major development that will limit the demand for painters is the increasing use of wood products that are finished with a prime coat and even a final coat before they leave the factory, thus reducing onsite painting. Within the next 10 years, as much as 50 percent of all wood products for exterior application reportedly will be preprimed and possibly prefinished. The use of glass, aluminum, and other building products that often require no painting is expected to continue increasing through the mid-1970's. In addition, new paints are being introduced that promise to have double the "life" of ordinary paints.

However, the development of paints with immense heat-resistant qualities, that are abrasion or corrosion resistant, and that are resistant to acids, alkalies, and other chemicals should lead to new applications for paints and additional jobs for painters.

Plumbers and Pipefitters (Construction Industry)

Employment Trends

Estimated employment of plumbers and pipefitters in the construction industry increased by 7 percent between 1950 and 1964, from about 198,000 to 212,000. Most of this increase can be attributed to growth in new construction activity.

Employment requirements for plumbers and pipefitters are expected to increase to approximately 265,000 in 1975, 25 percent above the 1964 employment level. Requirements are expected to rise because of an anticipated rapid expansion in construction activity, resulting primarily from rising population, family formations, and personal and corporate income. In addition, plumbing and heating work is expected to become more important in many types of construction. For example, the trend toward more bathrooms per dwelling unit is likely to continue. The installation of large appliances such as washing machines, dishwashers, and waste-disposal units will become more widespread. Also, an increase in the number of automatic heating systems is anticipated.

The demand for industrial installation work also will rise because pipework is becoming more important in many industries. For example, the chemical and petroleum industries, which use extensive pipework in their processing activities, are continuing to expand their facilities. In addition, the growing number of industrial activities associated with atomic energy and the increased use of industrial refrigeration and air-conditioning equipment should result in more work for plumbers and pipefitters.

Effects of Technological Developments on Future Employment

Technological developments are expected to limit growth in employment requirements for plumbers and pipefitters. A major development that is increasing the efficiency of plumbing and pipefitting work is the prefabrication of plumbing components. For example, prefabricated plumbing assemblies such as plumbing "trees" are available from manufacturers. These preassembled components include elbows, caps, T's, Y's, and ell's made of cast iron, copper, plastic, or galvanized steel. Such a system can be installed as one unit, thereby reducing the amount of onsite plumbing required. Packaged gas vents also are available. Vent pipe sections are being produced in standardized lengths that can be fastened together by locking-joint bands, thus eliminating cementing operations. In addition, some builders are preassembling their own waste, vent, and other system components. Well-equipped shops are being set up near the worksite where such work is performed by the employer's regular crew, often during times of inclement weather or other "slow" periods.

Improved materials also will increase construction put in place per plumber or pipefitter. For example, plastic piping is being used for a wide variety of plumbing operations including waste, sewers, vents, and cold water service. Plastic piping is light in weight, durable, easily joined with solvent, and plumbing "trees" made of this material can be easily handled by one man.

Stationary Engineers

Employment Trends

Employment of stationary engineers increased by almost one-fifth between 1950 and 1964, rising from about 215,000 to more than 255,000. This increase reflected the growing use of large stationary boilers, refrigeration and air-conditioning equipment, turbines, diesel and natural gas engines, pumps, compressors, and other equipment operated and maintained by these workers.

Almost one-half of all stationary engineers are employed in manufacturing industries, mainly in establishments producing electrical machinery, fabricated metals, food and kindred products, petroleum and coal products, and machinery (except electrical). Gas and electric utility firms, mines, and Federal, State, and local governments also employ large numbers of stationary engineers.

Employment requirements for stationary engineers are expected to rise by almost 8 percent between 1964 and 1975, to about 275,000. The increase in requirements for stationary engineers will result primarily from expansion of industrial, commercial, and governmental facilities that require the type of equipment these workers operate and maintain. The continued growth of pipeline transportation and saline water conversion also is expected to be a positive factor.

Effects of Technological Developments on Future Employment

Although the need for stationary engineers is expected to increase during the next decade, the growing application of technological developments will likely slow the rate of increase. Some of the major technological developments that are expected to offset the increased demand for stationary engineers are the growing use of larger equipment, centralized control panels, and automatic control systems.

The use of larger boilers, pumps, compressors, and other equipment makes it possible to increase capacity without corresponding increases in the number of stationary engineers. Increased use of centralized control panels in large establishments should increase the efficiency of stationary engineers. In a growing number of establishments, centralized control panels will be used in conjunction with closed-circuit television-monitoring systems, thus reducing the need for onsite observation of equipment. Automatic control systems, which regulate levers, throttles, valves, and other devices previously regulated by hand, also will increase the efficiency of stationary engineers.

Television and Radio Service Technicians

Employment Trends

Employment of television and radio service technicians increased from about 75,000 in 1950 to an estimated 110,000 in 1964. This increase can be attributed largely to the tremendous growth in the Nation's stock of televisions and other consumer electronic products. This growing use of home electronic products, in turn, was the result of rising levels of consumer income and the introduction of new and improved products. The number of households with television sets increased from less than a half million in 1947 to over 50 million in 1964.

About three-fourths of all television and radio service technicians, including the one-third who are self-employed, work in independent service shops or in retail stores that sell and service television receivers, radios, and other electronic equipment. Other service technicians are employed in a variety of industries, including government, electrical machinery manufacturing, and wholesale trade; however, less than 10 percent of these service technicians are employed in any one industry.

Employment requirements for television and radio service technicians are expected to rise by more than 25 percent between 1964 and 1975, to about 140,000. The projected increase in requirements for these service technicians is based on an anticipated rapid increase in the number of consumer electronic products in use during the decade ahead. The number of households with two or more television receivers is expected to increase significantly because of the growing demand for color and lightweight, portable, television receivers. Demand is expected to increase for other consumer electronics products such as stereophonic radios and phonographs, AM–FM radios, and portable transistor radios. Relatively new consumer products, such as home video-tape recorders, also should stimulate the need for additional service technicians. The factors expected to stimulate this growth in the use of home electronic products include large increases in population and in the number of households and higher levels of personal income. In addition, there should be a growing demand for nonentertainment electronic products, such as closed-circuit television to monitor production processes in manufacturing plants and to bring educational programs into classrooms.

Effects of Technological Developments on Future Employment

Employment requirements for television and radio service technicians are expected to increase somewhat slower than the stock of consumer electronic products because of technological improvements in these products that will tend to reduce the amount of service the equipment requires. Such changes as the replacement of tubes with transistors, use of printed circuit boards instead of hand-wired chassis, and solid-state amplifiers to replace amplifiers using vacuum tubes, have lengthened the period of time a product may be operated without requiring servicing. However, such changes, as well as the increasing miniaturization of components, mean that many of the newer products are more complex and require greater care, skill, and technical knowledge on the part of the service technician in order to repair them when something goes wrong. No longer is it a simple matter of testing the tubes in a television set and replacing the defective ones when the receiver operates improperly.

The stock of consumer electronic products is expected to continue to grow in complexity as new products, particularly color television, gain greater consumer acceptance. At present, a color television set is the most complex consumer electronic product ever developed. Other new products, such as the home video-tape recorder and home and commercial appliances utilizing microelectronic techniques, also utilize developments resulting from the rapid changes occurring in electronics technology, and can be expected to exert a strong influence on the skill requirements of television and radio service technicians. As a result, technicians will be required to keep abreast of technological developments in the electronics field in order to retain a place in the highly competitive television and radio servicing industry.

Operatives

Employment Trends

Employment of operatives increased about 5 percent between 1947 and 1964, rising from 12.3 million to 12.9 million. Employment fluctuated between 11.8 million and 12.8 million in the decade following World War II, but in 1958, the number of operatives declined to 11.4 million and remained between 11 million and 12 million for the next 3 years. Since 1961, however, there have been significant increases in employment of these workers, primarily reflecting the substantial increases in employment in manufacturing, in which large numbers of operatives are employed. In 1964, employment of operatives was 12.9 million, the highest number on record.

In 1964, an estimated 6 out of every 10 operatives were employed in manufacturing. About 40 percent of the operatives in manufacturing were employed in the following occupational categories: Assemblers; checkers, examiners, and inspectors; drivers and deliverymen; filers, grinders, and polishers; packers and wrappers; sewers and stitchers; welders and flame cutters; and production painters. Each of these occupational categories had more than 100,000 workers, and four of them—assemblers; checkers, examiners, and inspectors; sewers and stitchers; and drivers and deliverymen—had more than 500,000 workers each. The largest group of operatives outside of manufacturing were employed as drivers and deliverymen, numbering over 1.5 million workers. Many operative jobs are peculiar to particular industries; for example, almost all sewers and stitchers were employed in the apparel industry. On the other hand, some occupations, such as truck and tractor drivers, were distributed throughout all industries.

Employment trends among the individual occupations within the operatives group varied considerably, mainly reflecting the different rates of growth of the industries in which the workers were employed, but also as a result of the differing impact of technological innovations. For example, the increase in the number of assemblers and checkers, examiners, and inspectors resulted from the sharp growth experienced by the electrical machinery industries, and the development and widespread adoption of assembly-line production techniques. The rapid decline in employment of spinners and weavers reflected in large part the relatively small increase in demand for textile mill products and increased mechanization of spinning and weaving processes. Employment of truckdrivers increased sharply, as a result of the marked increase in the amount of freight carried by motor trucks.

Despite continued technological advances, which will adversely affect the demand for some operatives, overall requirements for these workers are expected to rise by 15 percent between 1964 and 1975, rising to 14.8 million in 1975. Increases in production generated by rising population and rapid economic growth, as well as a rising demand for transport of goods by truck, are expected to be the main factors bringing about the increased requirements for operatives.

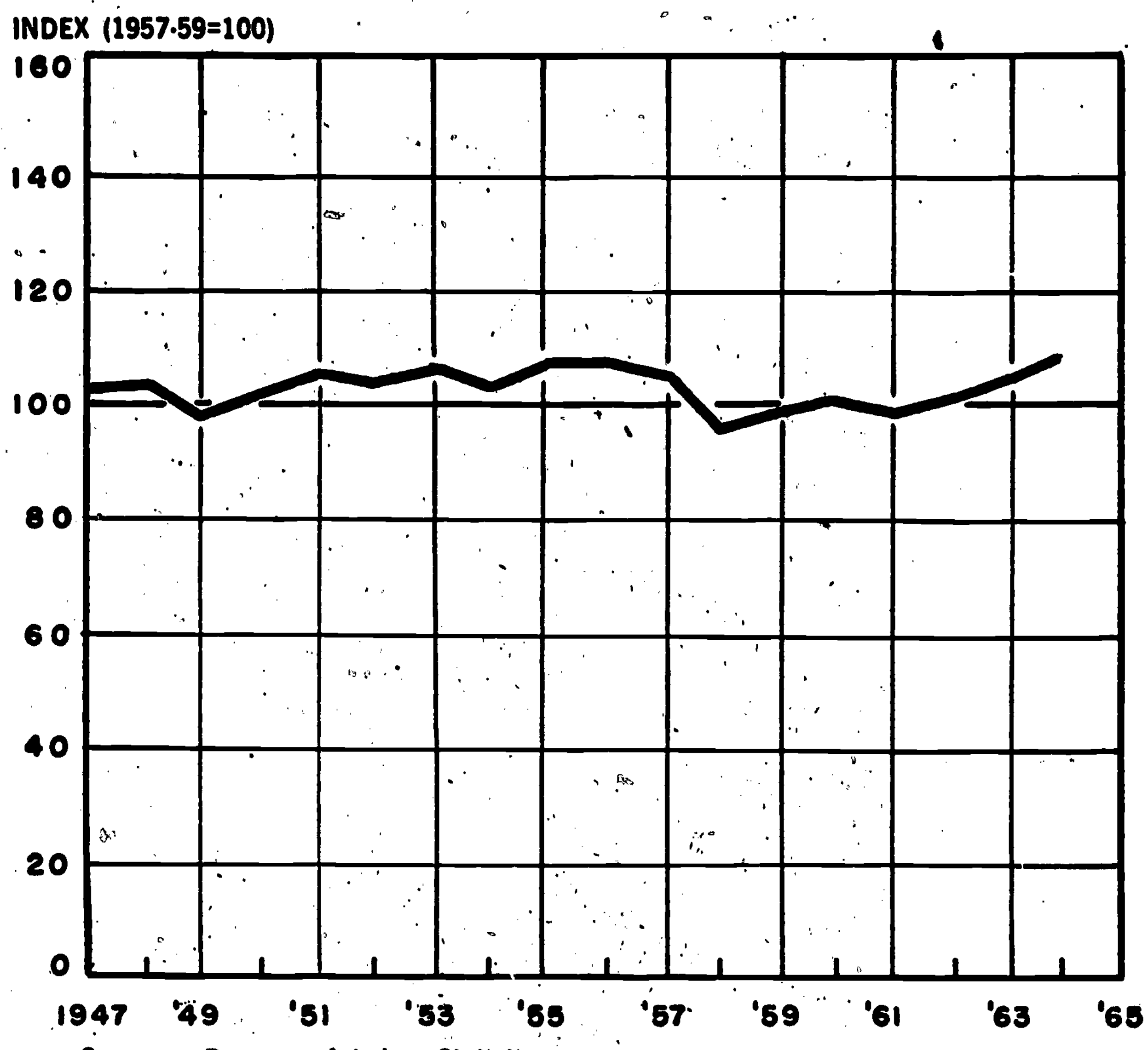
The rate of increase in requirements for the occupations within the overall operative group are expected to differ considerably. Requirements for assemblers are expected to increase relatively slowly over the next decade, as technological developments such as automation adversely affect the need for these workers. On the other hand, requirements for truckdrivers are expected to increase rapidly, as the volume of freight carried in trucks continues to increase.

Effects of Technological Developments on Future Employment

Technological innovations are expected to have the greatest impact on operative jobs in manufacturing. The rising use in the production process of mechanical devices and machines, such as automatic conveyor systems and process control systems, is expected to reduce unit labor requirements for operatives. The use of numerically controlled machines for lathing, drilling, milling, and boring of metal parts should limit the increase in requirements for machine tool operators. On the other hand, truck drivers are not expected to be significantly affected by technological innovations, despite the development of bigger trucks and better highway systems. Some new jobs for operatives will be created in industries which produce technological innovations, such as the instruments and electrical equipment industry groups.

EMPLOYMENT OF OPERATIVES, 1947-64

Employment (in 000's)	
1947	12,274
1948	12,396
1949	11,780
1950	12,146
1951	12,623
1952	12,352
1953	12,747
1954	12,253
1955	12,762
1956	12,816
1957	12,530
1958	11,441
1959	11,858
1960	11,986
1961	11,762
1962	12,041
1963	12,506
1964	12,924



Source: Bureau of Labor Statistics

Assemblers

Employment Trends

Estimated employment of assemblers increased from about 380,000 in 1950 to over 610,000 in 1960. Since 1960, employment in this occupational group has increased less than 2 percent (to about 620,000) despite a substantial growth in production in the durable goods industries, where over 90 percent of all assemblers are employed. Probably the major factor limiting employment growth of assemblers during the past several years has been the increasing mechanization and automation of assembly operations.

Assemblers make up one of the largest groups of semiskilled workers. The great majority of all assemblers are employed in the production of durable goods such as automobiles, aircraft, television and radio receiving sets, cameras, watches, refrigerators, and electrical motors. More than 40 percent of all assemblers are women, the majority of whom work in the electrical equipment, machinery, and supplies industry. Large numbers of women assemblers also are employed in the fabricated metals, transportation equipment, and instrument and related products industries.

In spite of technological developments that will make it possible to automate more assembly operations, and new tool designs that permit more than one operation to be performed simultaneously, employment of assemblers is expected to continue to increase because of the rapid growth of the electrical machinery and electronics industries, where a large proportion of these operators are employed. Between 1964 and 1975, employment requirements for assemblers are expected to increase by about 55,000, or 8 percent, to about 675,000.

Effects of Technological Developments on Future Employment

Employment requirements for assemblers are expected to increase slowly, despite rapid increases in industrial production, because of continued emphasis on the mechanization of assembly operations. Factors expected to hold down employment requirements for assemblers include the increasing use of automated assembly lines; new tools designed to simplify assembly processes; and product adaptation such as the substituting of printed electric circuits for manually wired products.

Inspectors

Employment Trends

Estimated employment of inspectors increased from 332,000 in 1950 to 540,000 in 1964, an increase of about 62 percent. Employment of inspectors increased primarily as a result of the widespread adoption of assembly-line production processes following World War II, and the rapid increases in the output of most manufacturing industries. For example, in the electrical machinery industry group, small components of appliances, instruments, and electronic devices were assembled more and more through division of the overall assembly task into small operations performed by many different workers. As a result, inspectors were needed for quality control at all stages of the production process, including the making up of subassemblies and the final product assembly. In addition, the increased number and complexity of manufactured products required additional inspectors to assure adequate quality control.

Inspectors are employed in all manufacturing industries. The machinery and electrical equipment industry groups employed the largest number of inspectors, each with about one-fifth of the total. Other large numbers were employed in the transportation equipment, fabricated metal products, textile mill products, apparel, primary metals, and stone, clay, and glass products industry groups.

Employment requirements for inspectors are expected to reach to 615,000 in 1975—a 1.3 percent annual rate of increase compared with 3.6 percent between 1950 and 1964. The increasing requirements are expected to result from the anticipated rapid rise in output in manufacturing industries and the increasing complexity of many manufactured products. Employment growth of inspectors will be tempered, however, by the increasing use of devices to reduce inspection requirements or to increase the efficiency of inspectors.

Effects of Technological Developments on Future Employment

Technological developments are expected to affect future requirements for inspectors in many ways. Increasing use of sensing and feedback instruments and controls in the processing of many durable and nondurable products reduces inspection requirements considerably. Accuracy is continuously monitored by some equipment; in some instances, the equipment will automatically reject products not up to specifications; in others, only an occasional sample will require the close scrutiny of an inspector. Although automation of assembly operations is expected to increase in the years ahead, it most likely will not be accompanied by the widespread automating of inspection functions. In many cases, such technological advances may actually increase the need for inspectors, mostly to look for and correct machinemade errors. Furthermore, many inspection functions now included among the duties of assemblers may be transferred to inspectors as the manually executed functions associated with assembly of parts are performed increasingly by mechanical devices. Requirements for inspectors also may increase to assure that the closer tolerances of parts required by more complex equipment are met.

Machine Tool Operators

Employment Trends

Estimated employment of machine tool operators increased from 450,000 in 1954 to more than 500,000 in 1964, an increase of about 11 percent over the 10-year period. The increased employment of machine tool operators resulted primarily from the expansion of metalworking activity in the automotive, machinery, fabricated metals, and other metalworking industries during this period. However, employment of machine tool operators rose much less rapidly than output in these industries, as a result of the increased use of automatic transfer equipment, and improvements in the power, speed, and specialization of conventional tools. Largely because of such cumulative developments, machine tool productivity has increased steadily. Numerically controlled machine tools have gained increasing, although still limited, acceptance in the metalworking fields, resulting in further increases in the efficiency of machine tool operators.

The vast majority of machine tool operators are employed in the metalworking industries, primarily in the machinery, except electrical; transportation equipment; fabricated metal products; and electrical machinery and equipment industries. Skilled machine tool operators may work in job shops, production departments, maintenance departments, and toolrooms.

During the 1964–75 period, employment requirements for machine tool operators are expected to decline slightly, from 500,000 to 480,000, as laborsaving technological developments more than offset the anticipated expansion in metalworking activities. The substantial increases expected in population, in the number of households, and in disposable income are expected to result in a rapid increase in the demand for metal consumer products such as automobiles, heating and air-conditioning equipment, and household appliances. Higher levels of corporate income and rising expenditures for industrial plant capacity should stimulate the demand for machinery, machine tools, engines, materials-handling equipment, instruments, and other machined products. In addition, expanded activity in the construction industry is expected to increase the demand for construction machinery. Despite this anticipated expansion of metalworking activities, employment requirements for machine tool operators are expected to decline because of technological developments that will increase significantly the efficiency of machine tool operators.

Effects of Technological Developments on Future Employment

Employment requirements for machine tool operators are expected to be adversely affected by the expanded use of numerically controlled machine tools and other laborsaving technological developments. Numerical control of machine tools constitutes a key technological development in the evolution of machine tools. Previous changes in machine tools largely involved improvements in power, speed, and specialization of machine tools. But, numerical control provides for the mechanized control of machine tools by means of electronic devices and changeable tapes on which directions have been punched. It constitutes a technique for significantly reducing unit labor requirements in many ways: (1) Numerical control is more continuous since the machine tool operator does not need to check and recheck his work against blueprints; (2) tool operations are more uniform, since the operator need not slow up as the work approaches completion; (3) since the use of numerical control results in more accurate machining, less work has to be redone—again increasing the efficiency of machine tool operators; (4) tooling and setup time are significantly reduced because of the substitution of tape controls for conventional jigs and fixtures.

Numerical control also will tend to change, to some degree, the content and skill requirements for some machine tool operator jobs. Using a conventional machine tool, some operators must set up the machine, select the cutting speeds and feeds, and continually adjust the machine settings to achieve specifications. With numerical control, these duties are automatically carried out by coded tape instructions. The operator of a numerically controlled machine tool is primarily responsible for tending or watching the highly automatic equipment as it goes through a series of operations. If a malfunction occurs, the operator is normally required to notify his supervisor, rather than make adjustments himself.

Employment requirements for machine tool operators also may be reduced by the increased utilization of automatic transfer equipment. Transfer machines are multistation machines within which the workpiece is automatically moved from station to station. Separate machining operations are usually performed automatically at each station. However, the use of automatic transfer equipment is economically feasible only in establishments producing large quantities of a standardized product.

Improvements also are being made in the machinability of metals. For example, the machinability of steel is improved by the addition of elements such as nitrogen, sulfur, and lead. This trend toward improved machinability of metals is expected to continue, thereby increasing the efficiency of machine tool operators by reducing the "down time" of metalworking machinery. Thus, despite the increase in overall metalworking activities, the above-mentioned developments, combined with the increased cutting speeds of conventional machine tools, are expected to reduce employment requirements for machine tool operators.

Laborers, Except Farm and Mine

Employment Trends

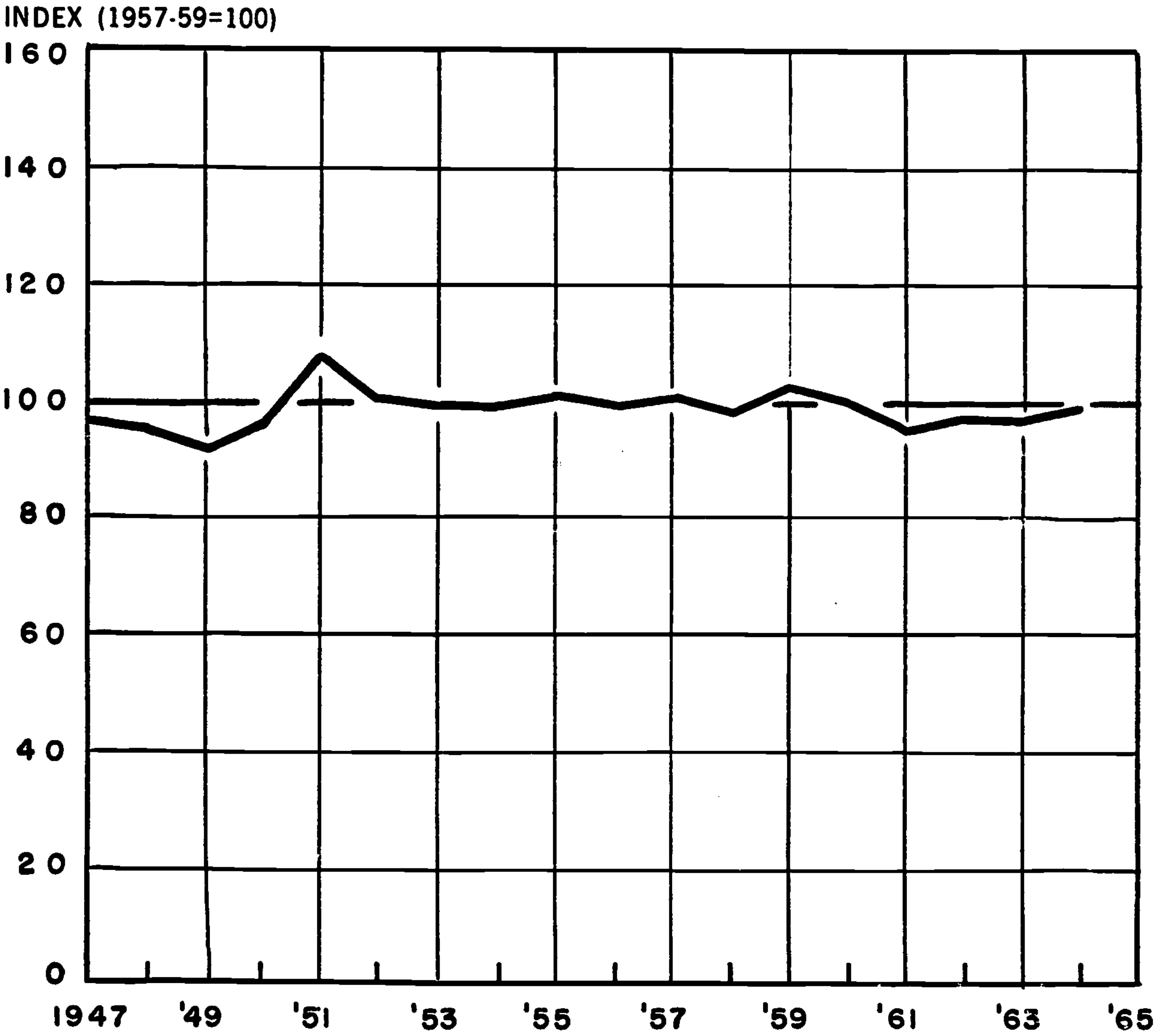
Employment of laborers increased from 3.5 million in 1947 to 3.9 million in 1951. Between 1951 and 1964, employment declined to 3.6 million. The decline in the employment of laborers occurred despite a substantial rise in business activity. The major factor reducing requirements for laborers during this period was the use of mechanized equipment to replace manual labor in such materials-handling jobs as loading and unloading, hauling, hoisting, wood chopping, wrapping, and mixing.

About one-third of all laborers are employed in manufacturing establishments and one-fifth work in the construction industry. Others are employed in a wide variety of industries, including wholesale and retail trade and transportation; however, less than 10 percent are employed in any one industry.

Employment requirements for laborers are expected to change very little between 1964 and 1975, in spite of a rapid rise in manufacturing and construction activity. Increasing demand is expected to be roughly offset by rising output per worker resulting from continuing substitution of mechanical equipment for manual labor.

EMPLOYMENT OF LABORERS, EXCEPT FARM AND MINE, 1947-64

Year	Employment (in 000's)
1947	3,526
1948	3,473
1949	3,365
1950	3,520
1951	3,952
1952	3,707
1953	3,656
1954	3,603
1955	3,681
1956	3,670
1957	3,680
1958	3,600
1959	3,743
1960	3,665
1961	3,477
1962	3,559
1963	3,551
1964	3,624



Source: Bureau of Labor Statistics

Effects of Technological Developments on Future Employment

Employment requirements for laborers are expected to change little between 1964 and 1975. Technological developments are expected to continue to limit employment requirements for laborers.

Manufacturing plants, freight terminals, and warehouses will use power-driven equipment such as forklift trucks, derricks, cranes, hoists, and conveyor systems to perform an increasing amount of their materials-handling work. This type of equipment can move larger amounts of raw materials and manufactured products and parts from place to place within a factory or warehouse than is possible when using manual workers. In addition, integrated systems of processing and materials-handling equipment will be installed in an increasing number of manufacturing plants in the years ahead. For example, in sawmills the use of electronic computers allows a console operator to control the cutting and moving of lumber without manual handling.

In the construction industry, the increasing use of mechanized equipment to do work formerly done by laborers also will tend to reduce requirements for these workers. For example, construction materials formerly handled manually at the construction site, such as brick, concrete, and lumber, now are being moved by forklift trucks, powered wheelbarrows, and conveyor belts. Materials are lifted to the upper floors of multistoried buildings by automatic lifts and heavy cranes. The growing use of earth-moving machines, including specialized equipment such as hole drillers, trenchers, and front-end loaders, to do excavating, ditch-digging, and similar work, also will reduce the need for construction laborers.

Service Workers

Employment Trends

Employment of service workers increased by about 55 percent during the 1947–64 period, rising from nearly 6 million in 1947 to about 9.3 million in 1964. This rate of growth was exceeded only by professional, technical, and kindred workers. The major factors underlying the increased employment of service workers during this period were population growth, higher levels of business activity, increases in leisure time, rising standards of living, and growth of disposable personal income.

Service workers represented about 13 percent of all employed persons in 1964 and included groups as diverse as firemen and waiters. About one-fourth of all service workers were employed in private households, performing such homemaking tasks as dishwashing, laundering, bedmaking, and preparing and serving meals. Women make up an exceptionally high proportion of private household workers, about 97 out of every 100. This group is also characterized by extensive part-time employment. About two-thirds of all private household workers are employed on a part-time basis.

Service workers employed outside private homes are concentrated in establishments providing a wide variety of services, wholesale and retail trade, and government. About half of the nearly 7 million service workers employed outside private homes in 1964 worked for one of the various service industries. Included were thousands of nurses' aids and other hospital attendants; cooks and kitchen workers in hospitals and schools; barbers; beauty operators; and maids, porters, and other hotel workers. In trade, the great majority were cooks, kitchen workers, fountain and counter workers, and waiters and waitresses who work in restaurants, drugstores, and other retail establishments where food is served. In government, many service workers were employed as firefighters, and policemen and other law-enforcement officers.

Employment requirements in service occupations are expected to increase by more than one-third between 1964 and 1975, to about 12.5 million. The variety of occupations within the service group, however, are likely to be affected quite differently—some growing rapidly, others moderately, and a few actually declining.

The greatest growth in requirements is expected to be for policemen and other protective service workers; attendants in hospitals, and in businesses rendering other professional and personal services; nurses' aids; beauty operators; cooks, waiters, and others who prepare and serve meals outside private homes; and janitors, caretakers, and building cleaners. Some of the factors expected to increase requirements for these occupations are the rising demand for hospital and other medical care resulting from increases in population and medical insurance coverage; the greater need for protective services as urbanization continues and cities become more crowded; and the more frequent use of restaurants, beauty parlors, and other services as population and income rise and as an increasing number of housewives take jobs outside the home.

Little, if any, of the anticipated employment increase during the next decade is likely to be among workers employed full time in private homes.

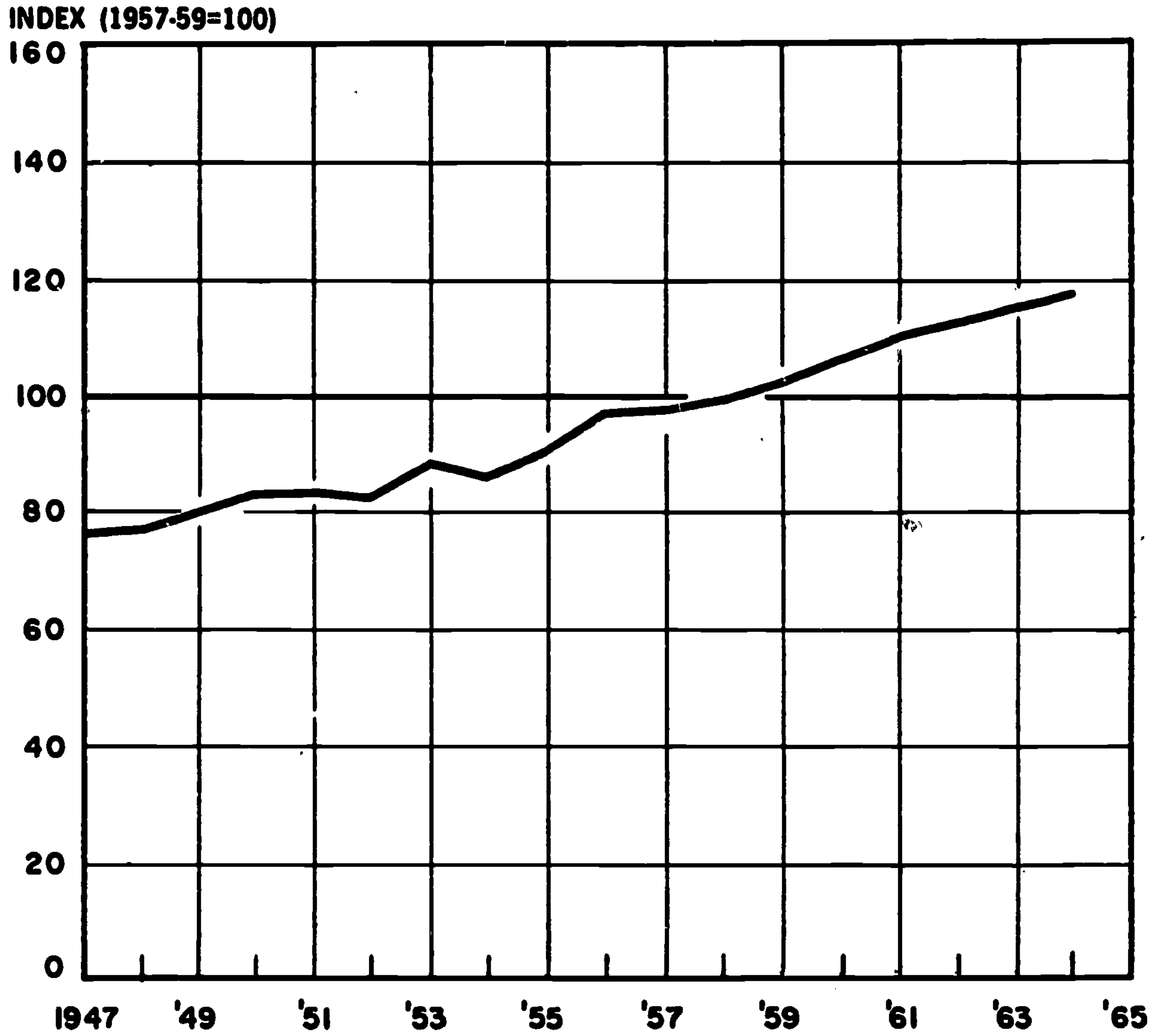
Effects of Technological Developments on Future Employment

The nature of the service occupations, especially the necessity for extensive person-to-person contact, limits the application of laborsaving technological innovations. Overall, the number of jobs eliminated by laborsaving technological innovations such as automatic drycleaning machines, automatic elevators, and computer controlled traffic signals is expected to be small compared with the number of new jobs created as the demand for service workers expands with increased population, economic activity, and higher income levels.

The more widespread use and development of new products and equipment will reduce employment requirements in some service occupations, however. For example, frozen foods, drip-dry textiles, and garbage-disposal units each reduce the unit labor needs in such occupations as kitchen and laundry worker and housekeeper. Similarly, because of electromechanical equipment, more and more elevators are operated automatically by passengers. Thus, elevator operator has been added to such service occupations as porter, bowling pinboy, and bootblack which are declining in size because of technological innovations.

EMPLOYMENT OF SERVICE WORKERS, 1947-1964

Year	Employment (in 000's)
1947	5,987
1948	6,040
1949	6,266
1950	6,535
1951	6,533
1952	6,488
1953	6,949
1954	6,755
1955	7,106
1956	7,609
1957	7,632
1958	7,809
1959	8,040
1960	8,349
1961	8,640
1962	8,8C2
1963	9,031
1964	9,256



Source: Bureau of Labor Statistics

Farm Workers

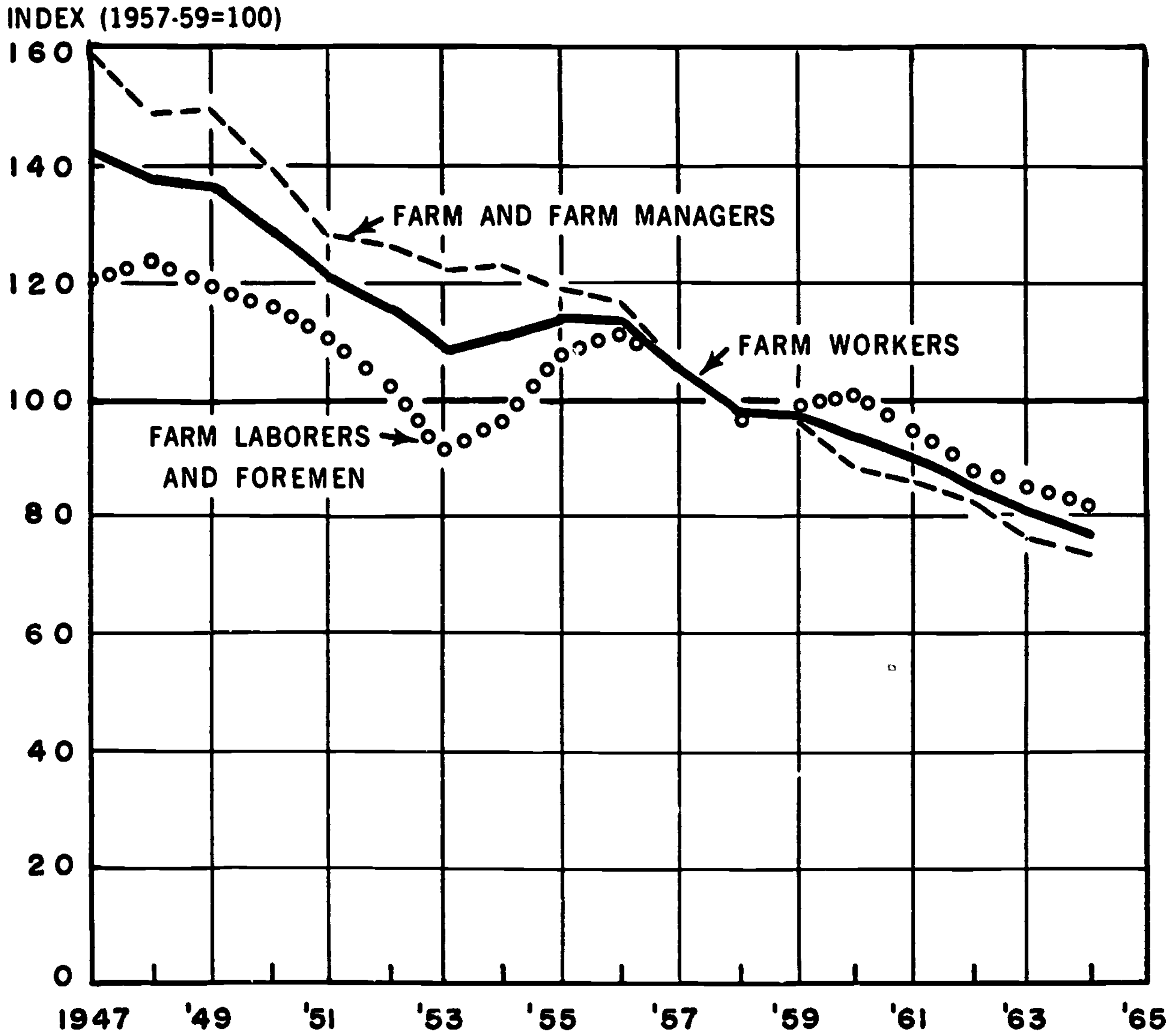
Employment Trends

Average annual employment of farmworkers, including farmers, managers, laborers, and foremen, decreased from about 8.1 million workers in 1947 to approximately 4.4 million in 1964, a decline of 45 percent. Farmers and farm managers declined faster than the group as a whole, from nearly 5 million in 1947 to 2.3 million in 1964, a drop of 54 percent. Farm laborers and foremen declined about one-third over the period, from 3.1 million workers in 1947 to 2.1 million in 1964. The decline in the employment of farmworkers during the 1950's and early 1960's occurred despite a substantial rise in farm output. The major factors reducing requirements for farmworkers during this period were the increasing size and efficiency of farms and the mechanization of many farm operations. In 1947, 1 farmworker produced enough food and fiber for himself and 14 others; today, he produces enough for himself and 31 others.

Employment requirements for farmworkers are expected to decrease to about 3.5 million workers by 1975, more than one-fifth below the 1964 level. This decrease is anticipated because of continued improvements in farm technology and a continued trend toward larger and more efficient farms. Farmers and farm managers are expected to continue to decline faster than farm laborers and fore-

EMPLOYMENT OF FARM WORKERS, 1947-64

Year	Employment (in 000's)
1947	8,120
1948	7,881
1949	7,819
1950	7,408
1951	6,900
1952	6,632
1953	6,224
1954	6,348
1955	6,537
1956	6,544
1957	6,059
1958	5,591
1959	5,582
1960	5,395
1961	5,170
1962	4,866
1963	4,615
1964	4,444



Source: Bureau of Labor Statistics

men because of a continued decline in the number of small farms.

The overall output of farm products is expected to continue to increase in the years ahead. However, unlike many other segments of the economy, farm output is not expected to be stimulated by significant increases in per capita consumption of its products. Increases in domestic farm production will result primarily from population growth. Exports of farm products, which currently represent about a sixth of farm income, are expected to continue to grow, but at a somewhat slower rate than domestic consumption.

Effects of Technological Developments on Future Employment

Despite an increase in agricultural production, employment requirements for farmworkers are expected to decline because of technological developments that will increase output per farmworker. The aims of modern agricultural technology are to give the farmer better control over nature and to reduce the amount of labor required in farming operations. Significant achievements have already been made in these areas and more are expected in the future. Technological innovations are expected to increase the productive output of land and animals, or reduce production risks inherent in farming operations. For example, improved fertilizers, seeds, and feed will permit the farmer to meet increased production demand without corresponding increases in employment. Improved irrigation and pest control methods and the use of crop varieties that resist drought, wind, and disease will reduce the risk of crop failure, thereby increasing output per farmworker.

Agricultural mechanization will enable farmers to reduce labor requirements or to meet increased production demands without corresponding increases in employment. For example, the development of improved mechanical harvesters for vegetables and fruits will decrease the need for seasonal and other hired workers. The use of machinery for thinning and weeding also will reduce the need for hired farmworkers. Innovations in livestock and poultry feeding and improved milking systems will allow farmers to handle a greater volume of production more efficiently. The expected development of automatic packing, inspection, and sorting systems for fruits, vegetables, and other farm products also will reduce employment requirements for farmworkers.

The continuing trend toward larger and more efficient farms can be expected to accelerate the pace of technological innovation in this industry. Because larger farms tend to employ more capital and less labor than the smaller units they displace, total employment opportunities for farmworkers are reduced. On the other hand, the skill requirements for many jobs on large farms increase because of the application of more efficient farm methods and the use of more complex tools and machines.

PART IV. FACTORS AFFECTING OCCUPATIONAL EMPLOYMENT PATTERNS

In today's technologically oriented society, there appears to be a general public awareness that technological change materially affects the occupational requirements of the economy. It is generally agreed that the introduction of new machinery and production processes usually has a direct impact on employment, often causing displacement of individual workers and sometimes overall employment declines in an occupation. There is considerably less awareness, however, that many factors other than technological developments also influence the level of employment in a particular occupation.

Part IV provides a discussion of the many factors which influence occupational employment.[79] The first section discusses the effects of changing technology as evidenced by the changing occupational patterns of selected industries. The second section describes the effect of factors other than technological change.

The Effects of Changing Technology on Occupational Patterns

Although many factors other than technological changes have had and will continue to have a significant impact on the occupational structure of the labor force, technological change is nonetheless a major determinant of occupational employment shifts. However, technology is inextricably woven with the other factors influencing employment, and the impact of technology itself is often hard to distinguish. This section of Part IV provides illustrative examples of the diverse effect that technological change has on occupations, as evidenced by the changing occupational composition of selected industries.

One impact of technological change on industry occupational patterns can be seen most clearly in industries which are declining in employment. In these industries, the greatest decreases in employment have usually taken place among laborers and others in the least skilled groups. One example is the *railroad industry*, which, under the impact of changes in technology, in the scale of operations, and in product mix, showed both very substantial declines in total employment and significant alterations in occupational composition over the 13-year period 1947 through 1960.[80] During this time, the diesel engine completely supplanted the steam locomotive, and there were substantial technical improvements in the method of maintaining track and roadbed. At the same time, passenger traffic declined substantially and freight traffic remained reasonably stable.

The effect of these changes is clearly reflected in the occupational composition of the industry. Employment dropped by more than 40 percent between 1947 and 1960, for a net loss of nearly 572,000 jobs. However, maintenance-of-way employment dropped by 55 percent, with the 69-percent decline in unskilled section hands (who did common labor on the tracks but were replaced by mobile-powered units that made repairs while moving slowly over the track) being offset to some extent by the 47-percent increase in the number of semiskilled portable equipment operators. Because diesel-electric locomotives require much less repair work than steam locomotives, skilled workers in repair employment dropped by 35 percent. Boilermakers were the hardest hit craft; their number declined by 82 percent. On the other hand, employment of electrical workers increased by 15 percent. Other occupational groups had smaller declines than the 40-percent drop in the industry as a whole. Professional, clerical, and general office employees declined by only 27 percent (affected to some extent by the introduction of electronic data processing) and executives declined by only 1 percent. The net effect of these occupational changes was that executive and office-workers increased as a proportion of total employment and unskilled workers and some maintenance crafts decreased.

The *lumber and wood products* industry is an example of a growing industry in which the number of unskilled jobs declined as mechanized equipment was installed. Employment dropped by more than 180,000 during the 1950–60 period, an average of about 2 percent per year. At the same time, output rose considerably, owing mainly to the use of faster and more powerful laborsaving

[79] The material in Part IV is drawn in large part from *Effects of Technological Change on Occupational Employment Patterns in the United States*, a paper prepared by Ewan Clague, former Commissioner of Labor Statistics, for the Conference on the Manpower Implications of Automation, Organization for Economic Co-Operation and Development, Washington, D.C., Dec. 8, 1964.

[80] *Employment and Changing Occupational Patterns in the Railroad Industry, 1947–60* (BLS Bulletin 1344, February 1963).

machinery such as high-speed handling, sawing, sorting, and stacking equipment. Woodchoppers and unskilled lumbermen decreased significantly between 1950 and 1960, while operators of portable spars, mechanical lumberjacks, and loading and other equipment increased.

In *banking*, technological changes have affected the occupational structure in still another way. Occupational patterns changed rapidly as this fast-growing industry expanded its use of electronic data processing equipment.[81] The sharpest reductions in manpower requirements for a given volume of work were in the demand deposit sector, where the needs for bookkeepers, proof and transit clerks, and many other routine clerical workers were reduced substantialliy through the use of magnetic ink character recognition, electronic bookkeeping machines, and full-scale computer systems. On the other hand, among the new jobs created were reader-sorter operator, check encoder or inscriber, control clerk, and keypunch operator; a few new jobs for programers and systems analysts were created at the professional and technician level. About half the people employed in banking—tellers, secretaries, typists, switchboard operators, officers, and professional workers—were not markedly affected by technological change and their employment continued to rise as banks increased their facilities and added new services. (The Bureau of Labor Statistics projections presented earlier in this report show that employment requirements in banking may rise by about 340,000 between 1964 and 1975, despite the rapidly expanding use of electronic data processing equipment and other innovations.)

Another example of the effects of the introduction of electronic computers on office employees can be seen from a study made by the Bureau of Labor Statistics of the *tax return processing* in a southern region of the United States.[82] This study shows that large numbers of routine and repetitive clerical jobs, particularly those relating to posting, checking, and maintaining records, were cut substantially. Also reduced significantly were the number of operators of bookkeeping machines and other office equipment. However, large numbers of keypunch operators (also classified as clerical workers) were hired to transcribe data from tax documents to punchcards for processing by computers. Another major effect was the reduction in the number of lower level supervisory jobs resulting from the elimination of certain routine clerical functions. Some new occupations related to administering and operating the computer system—systems analyst, programer, and console operator—were created.

[81] "Changing Manpower Requirements in Banking," *Monthly Labor Review*, September 1962.
[82] *Impact of Office Automation in the Internal Revenue Service* (BLS Bulletin 1364, 1963).

Examples of the contrasting effects of technology are shown in the changing occupational distributions of the petroleum and baking industries. (See table 3.) In the *petroleum refining industry*, between 1950 and 1960, laborers decreased in number and proportion, whereas craftsmen and professional workers increased. The increase in employment of craftsmen resulted largely from the growing amount of maintenance needed in the highly instrumented and automated petroleum refining processes. Employment of technicians increased because of the greater utilization of automated and computerized systems.

In the *baking industry*, on the other hand, the biggest increase in the proportion of total employment occurred among sales workers and operatives, whereas craftsmen declined as a proportion of the total. The decline in the relative importance of craftsmen reflected changes in technology, such as the introduction of continuous mixing units and modernized ovens in which products are baked while passing through the oven on a conveyor. In addition, because new methods were developed to freeze perishable items, they were produced in much larger quantities, contributing to the reduction in the relative number of skilled bakery workers required. The increase in sales workers was related to the greater number of driver-salesmen required to handle the much larger volume of bakery products. The increase in proportion of semiskilled workers resulted to a great extent from the large expansion in the number of truckdrivers—more than offsetting the decrease in operatives needed because of the introduction of automatic slicing, packaging, and other machines.

Change in technology in the *telephone industry* resulted in an occupational shift different from those previously described. As table 4 shows, the greatest shift was the decrease in the proportion of telephone operators and other clerical workers

TABLE 3. CHANGES IN OCCUPATIONAL EMPLOYMENT IN THE PETROLEUM REFINING AND BAKERY INDUSTRIES, 1950–60

Occupation	Bakeries		Petroleum refining	
	1950	1960	1950	1960
Total employed (in thousands)	267.0	362.1	257.2	252.7
Total percent	[1] 100.0	[1] 100.0	[1] 100.0	[1] 100.0
Professional and technical	0.8	0.6	14.9	16.2
Managers, officials, and proprietors	6.6	6.1	5.9	6.0
Clerical workers	8.5	8.5	17.5	18.1
Sales workers	6.7	9.9	2.1	2.2
Craftsmen and foremen	31.7	27.4	21.7	23.7
Operatives	39.5	41.5	26.3	26.3
Service workers	3.1	3.0	2.3	1.7
Laborers	3.1	2.9	9.2	5.9

[1] Base used in computing percents was the employed less the number not reporting occupations.

SOURCE: Department of Commerce, Bureau of the Census.

TABLE 4. CHANGES IN OCCUPATIONAL EMPLOYMENT IN THE TELEPHONE INDUSTRY, 1950–60

Occupation	1950	1960
Total employed (In thousands)	594.8	692.5
Total percent	[1] 100.0	[1] 100.0
Professional and technical	4.9	6.5
Managers, officials, and proprietors	3.7	5.4
Clerical workers	62.5	55.5
Telephone workers	(44.2)	(31.8)
Sales workers	.3	1.1
Craftsmen and foremen	24.9	28.6
Linemen and servicemen	(22.0)	(25.5)
Operatives	1.2	.7
Service workers	1.6	1.7
Laborers	.8	.5

[1] Base used in computing percents was the total employed less the number not reporting occupations.

SOURCE: Department of Commerce, Bureau of the Census.

resulting from the conversion from manual systems to automatic dial services for local and long-distance calls, and the introduction of automatic timing and billing services. At the same time, linemen, telephone installers, and repairmen increased because of the growing number of telephones as well as the complexity and growing volume of telephone services.

Perhaps the most dramatic impact of technological change on employment has taken place on the farm. As a result of increased mechanization, the use of scientific methods, chemical fertilizers, better seeds, and the like, productivity in *agriculture* has increased much more rapidly than in most industries. Employment has declined despite the need to grow more food for the increasing population. Furthermore, the occupational structure of farm employment has been sharply affected. For example, between 1950 and 1960, farmers and farm laborers decreased by about 40 percent, but the number of professional workers in agriculture rose by about 20 percent—such workers include airplane pilots (for crop dusting), scientists, foresters, accountants, and veterinarians.

The above illustrative descriptions of the impact of technological developments on selected industries should not obscure the fact that the effect of technological change on the occupational structure of most industries is extremely complex and cannot be traced easily. For the most part, technological innovations are not adopted extensively in an industry or an individual plant at any single time. Instead, they are often adopted piecemeal in the form of a great many minor changes introduced in one establishment and then in another, and often in a gradual way within an establishment. In view of the multitude of small changes having a different effect on the occupational pattern of an industry, it is extremely difficult, particularly without comprehensive current data on changing occupational employment patterns in individual industries to determine the net effect of all technological changes.

Factors Other Than Technological Change Which Affect Occupational Employment

In addition to technological change, there are several other major factors affecting occupational employment patterns. The most important of these other factors are the different rates of employment growth among industries resulting from shifts in the distribution of income and changing patterns of consumption; growth in population and its changing age distribution; Government policy and Federal expenditures; institutional factors such as union-management relationships and practices; and the relative supply of persons in different occupations. These and other factors are discussed in the following pages.

Population Growth. One of the major determinants of occupational change is growth in population and its changing age distribution. Rapid increases in population bring about sharp rises in the demand for goods and services of all kinds, and result in employment increases in industries producing them. As the population grows, there is a concomitant increase in the demand for the products needed to feed, clothe, and house the increased numbers of people and as industry expands its production of goods to meet these needs, employment often expands also. Similarly, the growing population requires increased services, which results in a rise in volume of business in service-producing industries, and therefore in the demand for workers such as barbers, hairdressers, lawyers, bankers, and medical personnel. The increasing urbanization of the population is responsible for the expansion of State and local government employment in order to provide the public services needed for urban living, such as those provided by firemen and policemen. Often, many of these occupations increase nearly in direct proportion to the increase in population.

In addition to the impact of overall population growth, the changing age distribution of the growing population plays a major role in influencing employment growth in some industries and their occupations. For example, a very large part of the increase in professional workers has been due to the changing composition of the population. A greater number of teachers are needed to service the rising number and proportion of school-age children in the population. Similarly, the increasing number of older persons in the population tends to bring about an even greater increase in demand for medical personnel.

Government Policy and Federal Expenditures. Government policy and Federal, State, and local expenditures play a major role not only in determining the occupational composition of employment, but in providing and stimulating overall employment. It is estimated, for example, that nearly 3 million workers are currently engaged in federally sponsored defense-related activities. Expenditures for education increase not only the employment of teachers, but of the construction workers and others needed to build, maintain, and administer the schools. Similarly, occupations such as social workers, doctors, nurses, highway engineers, and many others are affected by the size and direction of government expenditures.

Of the Federal programs, defense and space activities, have had the greatest effect on the occupational distribution of employment in the United States. Large and rising Government expenditures for research and development, for example, are in great part responsible for the dramatic increase in the demand for scientists, engineers, and technicians. The distinctive manpower profile characteristic of today's defense work force—with its above-average proportions of professional, technical, clerical, and craft workers and below-average proportions of semiskilled operatives—may be seen in the comparison (for 1963) of broad occupational groups in manufacturing employment as a whole and in defense-related employment in private industry. (See table 5.)

As table 5 shows, 15 percent of the work force in the defense industry consists of professional and technical workers, as against only 9 percent in manufacturing as a whole. In fact, throughout the whole range of the more highly skilled administrative, clerical, and craft workers, the proportions in defense industry are higher than in manufacturing. Conversely, only 37 percent of defense employment (3 workers out of 8) are operatives or laborers while about half of manufacturing employment consists of these occupations.

Another illustration of the higher skilled structure of defense-oriented manufacturing can be seen in table 6, which compares the early 1965 occupational distribution in selected plants manufacturing military and space electronic end-products with that in plants manufacturing electronic consumer products, such as radios and television sets. In electronics manufacturing, employment in the production of military and space items consisted of 68 percent nonproduction workers and only 32 percent production workers, whereas in the manufacture of consumer products in that same industry, only 40 percent were nonproduction workers and 60 percent, production workers. Engineers and other technical workers were three times as numerous in military and space work; clerical and stenographic personnel were also much more numerous. Even among production workers there was a marked difference. Nearly one-third of the production workers in military and space products plants were skilled, the remaining two-thirds being semiskilled and unskilled. On the other hand, over 80 percent of the production workers in consumer products were semiskilled and unskilled (50 percent of the entire work force). The major factor is that military and space products are in the forefront of technological change, emphasizing custom production involving continued invention and improvement, whereas consumer products are primarily items mass produced in large volume.

TABLE 5. OCCUPATIONAL COMPOSITION OF MANUFACTURING AND DEFENSE-RELATED EMPLOYMENT IN PRIVATE INDUSTRY, 1963

Occupation	All U.S. manufacturing (percent)	All defense-related employment in private industry (percent)
Total	[1] 100	100
Professional and technical workers	9	15
Managers, officials, and proprietors	6	7
Clerical workers	12	15
Sales and service workers	5	6
Craftsmen	18	20
Operatives	43	31
Laborers	6	6

[1] Because of rounding, percents do not total 100.

SOURCE: *Monthly Labor Review*, May 1964, p. 514.

TABLE 6. ILLUSTRATIVE OCCUPATIONAL DISTRIBUTIONS IN ELECTRONICS MANUFACTURING PLANTS MAKING MILITARY AND SPACE PRODUCTS, AND IN THOSE MAKING CONSUMER PRODUCTS, EARLY 1965

Occupation	Military and space products	Consumer products
	Percent	
Total employment	100.0	100.0
Nonproduction workers	68.0	40.0
Engineers and other technical workers	35.0	12.4
Engineers	21.4	7.4
Technicians and draftsmen	13.6	5.0
Administrative and executive	17.4	16.1
Clerical and stenographic	15.3	11.1
Production workers	32.2	60.0
Skilled	10.5	10.7
Semiskilled and unskilled	21.7	49.8

NOTE: For further information see *Employment Outlook and Changing Occupational Structure in Electronics Manufacturing* (BLS Bulletin 1363, October 1963), p. 37.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics; based on information obtained through field visits to selected electronics establishments.

Employment Growth Among Industries. The different rates of employment growth among industries, as affected by the factors described above, may have been the most important single factor determining the occupational distribution of employment in the United States.[33] An examination of industry employment trends indicates that the very large increases in white-collar employment in the economy as a whole have resulted from the greater-than-average growth in industries employing large numbers of these workers—for example,

[33] Of course, growth of some industries is due to new technology and inventions, and decreases in some industries are due in part to increases in productivity.

State and local government, finance, insurance, and real estate, trade, and business and professional services—coupled with the much slower growth in industries in which smaller numbers of white-collar workers are employed—mining, manufacturing, and transportation. Of course, differences in industry employment growth also reflect shifts in the distribution of income and changes in patterns of consumption, which in turn may bring about changes in the demand for products of particular industries, and hence employment changes. Furthermore, the greater growth of some industries has resulted from technological developments, i.e., new inventions such as television. The rapid growth of the space program is another example of how technological innovations may bring about rapid industry employment growth.

A comparison of 1950 and 1960 census data shows further that, except for laborers, the changing employment levels of industries had a much greater effect than shifting occupational patterns within industries on the change in the number of persons employed in each occupational group. For example, among the sales, craftsmen, and operative groups, no increase in employment resulted from the net effect of changing occupational patterns of individual industries over the 1950–60 period. Similarly, nearly all of the 47-percent increase in employment in the professional group resulted from the changing levels of industry employment. Changing occupational patterns of individual industries apparently offset each other, so that there was only a very small net increase in the employment of professional workers which could be attributed to shifting occupational structures.

This conclusion is based on net growth of major occupational groups. Vast changes, however, may occur within each occupational group despite little change in the overall total. Although individual occupations in the same skill group may have divergent rates of growth, adding those occupations together often results in very little apparent change for the occupational group as a whole. For example, within the clerical occupational group, employment of telephone operators decreased slightly from 1950 to 1960, whereas the number of stenographers, secretaries, and typists rose by more than two-fifths. Similarly, within the craftsmen group, boilermakers decreased by one-third and air-conditioning and refrigeration mechanics increased by more than two-fifths during this period.

Another example of the importance of industry growth to occupational employment may be found in the recent employment rises in the manufacturing and construction industries resulting from high levels of high-economic activity nationally. Closely related to this recent expansion has been the sharp reversal of the half-decade downtrend in the number of workers employed in blue-collar jobs. Employment in these manual occupations increased by 700,000 between 1962 and 1963 and by over half a million between 1963 and 1964, as contrasted with the decline which totaled 600,000 jobs for the half decade between 1957 and 1962.

Industry growth rates can also be affected by other, closely related factors. For example, imposition of protective tariffs or import levels often insures domestic producers a growing market for their products. Similarly, the discovery of new natural resources may place the domestic producer in a much more competitive position vis-a-vis foreign exports, and thereby expand the demand for his product. The substitutability of new products can reduce the demand for some products, i.e., plastic for glass.

Union-Management Relationships and Practices. The occupational pattern of an industry may be influenced greatly by collective bargaining agreements and the relationship between labor and management. The construction industry is a good example of the influence labor-management decisions may have in maintaining occupations nearly intact through decades of technological change. The railroad, longshore, and newspaper industries are other cases where, in general, the influence of unions has been directed toward the maintenance of occupational skills. Union management decisions are often important enough to have a marked effect on the occupational patterns of the economy as a whole.

Collective bargaining agreements may also have a different type of effect on occupations. For example, union-management agreements providing for early retirements may serve to accelerate the rate of decline of occupations in which employees either are or may become surplus. On the other hand, agreements which provide for shorter working hours (as with truck and bus drivers) or longer holidays (such as in the steel, can, and aluminum industries) may increase or at least maintain the requirements for workers.

Supply and Demand Factors. Scarcities and surpluses among different occupations provide management with the opportunity to engineer the jobs to match in some degree the available supply of workers. For example, when engineers are in short supply, many routine engineering functions are reprogramed to be performed by technicians, and additional technicians are hired to perform these functions. In other cases, a production process or material may be adjusted so as to employ a combination of labor skills different from those in short supply.

Other Factors

One of the many other nontechnological factors which influence occupational employment is the Nation's social climate. Increasing concern with the problems of education, living conditions, health standards, and discrimination result in increased requirements for many occupations such as teachers, guidance counselors, and social workers. These requirements are over and above those created by population growth. Organizational changes and improvement in managerial practices also influence the growth rates of occupations. Mergers and acquisitions of firms often affect many middle-management jobs, as does the streamlining of administrative procedures. More liberal tax conditions, lower corporate tax rates, and new depreciation guidelines also affect occupations in that they may increase the profitability of new machinery and equipment.

PART V. PROJECTED CHANGES IN OCCUPATIONAL REQUIREMENTS AS THEY RELATE TO SELECTED SUBGROUPS OF WORKERS

Changing occupational requirements may affect important subgroups of the labor force quite differently. Part V illustrates some of the implications that appear to be pertinent to the future employment of nonwhite workers, younger and older workers, and women.

This report makes no attempt to forecast what the employment of these groups will actually be in 1975. On the contrary, the projections are based entirely on very specific assumptions, and serve only to illustrate important relationships between occupational changes and the employment characteristics of these subgroups.

Changing Occupational Requirements and Employment Opportunities for Nonwhite Workers

In recent years, nonwhite workers have had unemployment rates about twice as high as those for white workers. The average unemployment rate for nonwhites in 1964 was 9.8 percent, while for whites it was 4.6 percent. This disparity reflects, in part, the lower educational levels of nonwhites and their concentration in occupations subject to higher-than-average unemployment rates. They are concentrated disproportionately in laborer occupations—both in industry and on farms—and service occupations, and have lower proportions in white-collar and craft occupations than do white workers.

The occupations in which the greatest number of nonwhites are now employed will be growing more slowly than other occupations over the next 10 years. Therefore, if employment opportunities for nonwhites are to improve, or even remain the same, they must continue to gain access to the rapidly growing higher skilled and white-collar occupations.

If the nonwhites were merely to continue holding the same proportion of the jobs in each occupation that they held in 1964—that is, if they were to make no advances in gaining access to the craft and white-collar occupations—the nonwhite share of total employment would decline, simply because of the slower growth of the occupations in which they are concentrated.

Table 7 illustrates what the plight of the nonwhite workers will be by 1975 if they continue to hold the same proportion of the jobs in each occupation group as in 1964. The total number of nonwhites employed in 1975 under these assumptions would be 8,970,000, an increase of about 1.5 million, or 20 percent, as compared to 1964.

TABLE 7. ILLUSTRATIVE PROJECTIONS OF EMPLOYMENT OF NONWHITE WORKERS IN 1975, ON THE ASSUMPTION THAT THEY WILL RETAIN THE SAME SHARE OF EMPLOYMENT IN EACH OCCUPATION AS IN 1964

[In thousands]

Occupational group	Employment, 1964			Hypothetical employment, 1975		
	Total	Nonwhite	Nonwhite as a percent of total	Total [1]	Nonwhite	Nonwhite as a percent of total
Total, all occupations	70,400	7,480	10.6	88,700	8,970	10.1
Professional, technical, and kindred workers	8,600	500	5.8	13,200	770	5.8
Managers, officials, and proprietors (excluding farm)	7,500	190	2.6	9,200	240	2.6
Clerical and kindred workers	10,700	570	5.4	14,600	780	5.3
Sales workers	4,500	140	3.1	5,800	180	3.0
Craftsmen, foremen, and kindred workers	9,000	530	5.8	11,400	670	5.9
Operatives and kindred workers	12,900	1,520	11.8	14,800	1,740	11.8
Laborers (excluding farm and mine)	3,600	970	26.9	3,700	1,990	26.9
Service workers	9,300	2,410	26.0	12,500	3,080	24.7
Farm workers	4,400	650	14.6	3,500	520	14.8

[1] Total employment has been projected earlier in this report.

NOTES: (1) Because of rounding, sums of individual items may not equal totals. (2) Total employment is rounded to the nearest 100,000 and nonwhite employment is rounded to the nearest 10,000; the percentages are derived from unrounded data. (3) The computations were done separately for the following occupational categories: Medical and other health; teachers, except college; other professional and technical; managers, officials, and proprietors; stenographers, typists, and secretaries; other clerical workers; retail trade sales workers; other sales workers; carpenters; construction craftsmen, except carpenters; mechanics and repairmen; metal craftsmen, except mechanics; other craftsmen and kindred workers; foremen, not elsewhere classified; drivers and deliverymen; other operatives; nonfarm laborers; private household workers; service workers, except private household; farmers and farm managers; and farm laborers and foremen.

This rate of increase in employment would be slower than that of white workers, whose employment is projected, under this assumption, to rise by about 27 percent.

The implications of this slower growth in employment for unemployment among nonwhites may be seen by comparing this estimate of their employment in 1975 with the nonwhite labor force projected for that year. Preliminary projections of the latter, consistent with the general labor force projections presented earlier in this report,[84] show a total nonwhite labor force of about 11 million in 1975. Assuming that the same number of nonwhites will be in the Armed Forces in 1975 as in July 1963 (about 200,000), we would derive a nonwhite civilian labor force of about 10.8 million. If approximately 9 million were employed, as computed above, the remainder—1.8 million—would be unemployed—*an unemployment rate of about 17 percent—over five times the unemployment rate for the whole labor force* assumed in the projections of employment.[85]

Actually nonwhites have made some gains in recent years in shifting to the higher skilled and faster growing occupations. As shown in table 8, nonwhites increased their share of the jobs in the white-collar occupations from 3.1 percent in 1954 to 4.5 percent in 1964. The gains took place in each of the major occupation groups of white-collar workers; the gain was steady over the whole 10-year period in clerical occupations, but among professional, sales, and managerial occupations the greatest increase took place after 1958.

There was a more modest gain in the nonwhite share of employment in blue-collar occupations—from 10.9 percent in 1954 to 11.8 percent in 1964. This reflected a slight decline in their share of laborer jobs, a slight gain among operatives, and a substantial gain among craft jobs.

In service occupations, where nonwhites have traditionally had a disproportionately large share of the jobs, their share decreased moderately, from 29 to 26 percent in the 1954–64 period.

Nonwhites moved out of farm occupations in roughly the same proportions as did white workers over the 10-year period. The nonwhite share of farm employment continued at about the same level, between one-sixth and one-seventh of the total. In 1964, it was 14.6 percent, slightly below the 15.3 percent of 1954.

If these trends continue, the effect would be to increase total nonwhite employment and to reduce the gap between white and nonwhite unemployment. To illustrate this, a computation of nonwhite employment in 1975 was made on the assumption that the changes in the period 1958 to 1964 in the proportion of jobs in each occupation filled by nonwhites would continue at the same annual rate in the period 1964 to 1975 (table 9). The period since 1958 was chosen because some of the major changes have occurred since then. Under this assumption, nonwhite employment would be about 10 million[86] in 1975, a gain of about 2.5 million, or about one-third, as compared to a little more than 25-percent gain in employment of white workers. With the same nonwhites civilian labor force estimated above—10.8 million—this would leave almost 800,000 nonwhite unemployed, *an unemployment rate of 7.5 percent—two and one-half times as high as the projected 3-percent unemployment rate for the whole labor force.* Thus, the present disparity in unemployment rates between whites and nonwhites would still remain in 1975 if the nonwhites continue to gain access to the higher skilled jobs at the same rate as in recent years.

In summary, the effect of the projected shifts in the occupational requirements of the U.S. economy on employment opportunities for nonwhites is such that *they will have to gain access to the rapidly growing higher skilled and white-collar occupations at a faster rate than they have in*

TABLE 8. NONWHITE EMPLOYED WORKERS AS A PERCENT OF TOTAL EMPLOYMENT IN EACH MAJOR OCCUPATION GROUP, 1954–64 [1]

Occupational group	1954 [2]	1955 [2]	1956 [2]	1957 [2]	1958	1959	1960	1961	1962	1963	1964
Total, all occupations	10.3	10.2	10.3	10.4	10.2	10.3	10.6	10.4	10.5	10.5	10.6
Professional, technical, and kindred workers	3.9	3.9	3.7	3.8	3.8	4.3	4.4	4.1	4.6	5.3	5.8
Managers, officials, and proprietors (excluding farm)	2.1	2.3	2.2	2.1	2.3	2.3	2.5	2.5	2.5	2.6	2.6
Clerical and kindred workers	3.7	3.8	3.8	4.4	4.3	4.4	5.2	5.4	5.1	5.1	5.4
Sales workers	2.3	2.0	1.8	1.9	2.1	2.1	2.6	2.5	2.6	3.0	3.1
Craftsmen, foremen, and kindred workers	3.8	4.0	4.2	4.4	4.5	4.5	4.9	4.9	4.9	5.2	5.8
Operatives and kindred workers	10.7	10.6	11.2	11.3	11.3	11.2	11.8	11.9	11.7	11.8	11.8
Laborers (excluding farm and mine)	27.5	27.6	26.7	27.3	26.6	27.7	26.4	25.7	27.0	26.2	26.9
Service workers	29.0	28.6	28.2	28.2	27.6	26.7	26.8	26.3	26.4	26.3	26.0
Farm workers	15.3	14.3	14.9	15.3	14.9	15.5	16.2	15.7	16.1	15.3	14.6

[1] Data through 1956 have not been adjusted to reflect changes in the definitions of employment and unemployment adopted in January 1957.

[2] Averages based on data for January, April, July, and October.

SOURCES: Bureau of the Census and Bureau of Labor Statistics.

[84] Estimates based on article by Sophia Cooper and Denis F. Johnston, "Labor Force Projections for 1970–80." *Monthly Labor Review*, February 1965.

[85] This makes no allowance for possible withdrawal from the labor force of nonwhites who would simply give up the search for work under such conditions.

[86] This represents about 900,000 more jobs for nonwhites than if the penetration rate were to remain at 1964 levels.

recent years if their unemployment rate is to be brought down toward the same level as that of their white fellow citizens. In part, this is a matter of providing educational and training opportunities; in part, of reducing racial discrimination in hiring.

TABLE 9. ILLUSTRATIVE PROJECTIONS OF EMPLOYMENT OF NONWHITE WORKERS IN 1975, ON THE ASSUMPTION THAT THEIR SHARE OF EMPLOYMENT IN EACH OCCUPATION CHANGES AT THE SAME ANNUAL RATE AS IN THE 1958–64 PERIOD

Occupational group	Employment, 1958			Employment, 1964			Hypothetical employment, 1975		
	Total	Nonwhite	Nonwhite as a percent of total	Total	Nonwhite	Nonwhite as a percent of total	Total	Nonwhite	Nonwhite as a percent of total
Total, all occupations	64,000	6,520	10.2	70,400	7,480	10.6	88,700	10,000	11.3
Professional, technical, and kindred workers	7,000	260	3.8	8,600	500	5.8	13,200	1,180	8.9
Managers, officials, and proprietors, (excluding farm)	6,800	150	2.3	7,500	190	2.6	9,200	300	3.2
Clerical and kindred workers	9,100	390	4.3	10,700	570	5.4	14,600	1,050	7.2
Sales workers	4,200	90	2.1	4,500	140	3.1	5,800	290	5.0
Craftsmen, foremen, and kindred workers	8,500	380	4.5	9,000	530	5.8	11,400	880	7.7
Operatives and kindred workers	11,[illegible]	1,300	11.3	12,900	1,520	11.8	14,800	1,900	12.8
Laborers (excluding farm and mine)	3,600	960	26.6	3,600	970	26.9	3,700	960	25.9
Service workers	7,800	2,150	27.6	9,300	2,410	26.0	12,500	2,960	23.7
Farm workers	5,600	830	14.9	4,400	650	14.6	3,500	500	14.2

See notes table 7.

Changing Occupational Requirements and Employment Opportunities by Age

Much has been written about the necessity of increasing employment opportunities for younger and older workers—for younger workers because their rates of unemployment are higher than those for the remainder of the labor force, and because the number of young workers will increase rapidly in the decade ahead; and for older workers because of the problems they face in adjusting to the job requirements of a rapidly changing economy. This section of Part V attempts to assess the impact of the projected changes in occupational requirements on employment opportunities if each occupation were to have the same age distribution in 1975 as in 1964.

The method used to develop the hypothetical estimates of manpower requirements by age presented in this section was a relatively mechanical one. In brief, the 1964 age distributions of workers in broad occupational groups and in a selected group of detailed occupations[87] were applied to the projections of 1975 requirements in each occupational group (presented in Part III) and aggregated to develop a hypothetical age distribution of civilian employment in 1975.

Like the earlier estimates of nonwhite employment presented in the preceding section, the illustrative estimates of hypothetical occupational requirements by age should not be construed as representing "projections" or "forecasts." Instead, they should be viewed as representing only a hypothetical situation in which the Nation's employers in 1975 utilize the same age distribution of their occupational employment as obtained in 1964. Such an approach, of course, does not allow for any changes in the age distribution which may have been occurring in recent years, nor does it allow for the possible differences in age between the actual 1964 age composition of an occupation, and that which employers might have wanted or accepted.

As indicated in Part II, total manpower requirements are expected to increase by more than one-fourth between 1964 and 1975, with some occupations increasing and others declining. Applying the actual 1964 age distribution of individual occupations to the comparable projected 1975 occupational requirements results in a hypothetical age distribution of 1975 employment which is somewhat different from that of 1964. A comparison of the actual 1964 age distribution and the hypothetical 1975 age distribution indicates that relatively fewer jobs will be available for younger workers and older workers. As table 10 shows, relative requirements for workers 14–19 years of age would decline from 7.9 percent of the total (employed civilian labor force) in 1964, to 7.6 percent in 1975. Similarly, requirements for workers age 55 and over would also decline, falling from 18.1 percent of the total in 1964, to 17.9 percent in 1975. These would be offset by somewhat higher proportions in the 25–54 age groups, as the following table shows.

[87] See earlier section on nonwhite workers for a list of the occupations included.

TABLE 10. AGE DISTRIBUTION OF 1964 EMPLOYMENT AND HYPOTHETICAL 1975 REQUIREMENTS

Age	Actual, 1964	Hypothetical, 1975
Number of workers	70,357,000	88,700,000
	Percent distribution	
Total, all ages	100.0	100.0
14-19	7.9	7.6
20-24	10.4	10.5
25-34	19.1	19.4
35-44	23.0	23.2
45-54	21.5	21.4
55-64	13.9	13.8
65 and over	4.2	4.1

SOURCE: 1964 data are computed from Special Labor Force Report No. 52, "Labor Force and Employment in 1964," *Monthly Labor Review*, April 1965. 1975 estimates are from the Bureau of Labor Statistics.

The relative decline in requirements for workers 14 to 19 years of age can be attributed in great part to the projected decline in employment of farmworkers. In 1964, a relatively high percentage of farmworkers were between 14 and 19 years of age, and as requirements for farmworkers continue to decline, this age group will be sharply affected.

The relative decline in requirements for workers 55 years and older also apparently results from decreasing employment of farmworkers. Increased requirements for managers, officials, and proprietors, which also had relatively large numbers of older workers in 1964, are not expected to be great enough to offset this decline in the number of farmworkers.

The implications of these changing patterns of requirements by age emerge more clearly through a comparison of the age distribution of the supply of workers expected to be available in 1975, projected independently by the Bureau of Labor Statistics.[88] Such a comparison indicates that some major differences could exist between the hypothetical requirements and the supply of workers by age.[89]

The major difference occurs in the proportion of workers in the youngest age groups—14–19 and 20–24 years of age. In both these age groups, the relative supply of workers in the labor force in 1975 exceeds the requirements indicated by the hypothetical 1975 employment based on the assumption that the age composition of occupations in 1975 will be the same as obtained in 1964. As table 11 shows, although nearly one-fourth (23 percent) of the projected civilian labor force may be young persons aged 14–24, the hypothetical age distribution of projected 1975 employment requirements indicates that less than one-fifth (about 18 percent) of the requirements will be for workers in this age group.[90] A similar, though smaller, difference exists for workers 25–34 years of age, who are expected to comprise 22 percent of the projected labor force compared with less than 20 percent of the hypothetical 1975 requirements. Among workers in the 35–54 age groups—sometimes called the prime working ages—the comparison shows the opposite effect—a smaller proportion of workers available (37 percent of the total civilian labor force) than are required (45 percent of the hypothetical requirements). In the remaining age groups—55–64 and 65 years and older—there appears to be rough comparability in requirements and supply.

TABLE 11. AGE DISTRIBUTION OF 1975 CIVILIAN LABOR FORCE AND HYPOTHETICAL 1975 REQUIREMENTS

Age	Civilian labor force	Hypothetical requirements
	Percent	
Total, all ages	100.0	100.0
14-19	9.7	7.6
20-24	13.5	10.5
25-34	22.4	19.4
35-44	17.5	23.2
45-54	19.5	21.4
55-64	13.9	13.8
65 and over	3.6	4.1

A number of possible implications emerge from these projected differences in requirements and supply. One possible implication is that employers may have to lower the minimum age at which they hire workers for particular occupations. Another is that industry patterns of utilization might have to change, with more young workers hired as aids and assistants to the relatively more scarce mature and experienced workers. Perhaps another implication might be that even more young workers than anticipated would delay their entry into the labor market in order to obtain the education and training needed to fill the available jobs. Still another might be that workers would have to be promoted to supervisory or foremen positions at an earlier age than formerly. (It might also mean better opportunities for younger workers to advance to middle-management positions.)

These possible alternatives are by no means the only ones, and by indicating them it is not meant to imply that they are either desirable or likely. They are presented only to illustrate the possible implications of the changing occupational requirements.

[88] See Special Labor Force Report No. 49, "Labor Force Projections for 1970–80," *Monthly Labor Review*, February 1965. These projections were adjusted upwards to reflect the larger labor force under a 3 percent level of unemployment.

[89] It should be noted that the hypothetical 1975 age distribution, based on civilian employment (less unemployed workers), is not directly comparable to the projected 1975 age distribution of the civilian labor force (including unemployed workers). However, since the purpose of the comparison is to examine the implications of the changing occupational structure, it was believed that the implications would be more clearly seen through a comparison with the total supply of workers rather than with employed workers.

[90] It should be reiterated that actual numbers of persons in these and other age categories are not directly comparable, since the total of projected requirements excludes the unemployed workers which are included in the civilian labor force.

Changing Occupational Requirements and Employment Opportunities by Sex

In recent years, one of the most striking aspects of the Nation's sharp increases in total employment has been the relatively more rapid growth in employment of women than of men. Since the end of World War II, employment of women rose from 16.3 million to 24.2 million, an increase of 48 percent—a rate of increase more than four times as rapid as the rate of increase for men. As a result, the proportion that women make up of total employment grew from 28 percent in 1947 to more than 34 percent in 1964. In the late 1950's, however, the rate of increase began to slow down, and between 1958 and 1964, employment of women rose only about twice as fast as employment of men (16 percent as compared with 7 percent). Thus, over the 1958–64 period, the proportion women comprised of total employment increased only from 32.7 percent to 34.4 percent. Similarly, only small changes in the proportion of women employed occurred in the broad occupational groups which make up total employment.

In order to evaluate the impact of the projected 1975 occupational requirements on employment of women workers, analyses similar to those described in the section on nonwhite workers were undertaken for male and female workers under two different hypotheses. The first hypothesis was that the proportion women make up of employment in each broad occupational group in 1975 would be the same as in 1964. The second hypothesis was that recent (1958–64) changes in the proportion of women workers in each occupational group would continue to 1975. These hypothetical proportions were then applied to the projections of 1975 requirements in these occupations, and the totals aggregated. The resulting hypothetical estimates show the proportion women would make up of total employment in 1975, (1) if the penetration rates for women workers were to remain at the 1964 level, and (2) if they were to continue to increase at the same rate as they did in the 1958–64 period.

The results of the above analyses indicate that the changing occupational requirements of the Nation would not have a significant effect on employment opportunities for women, and thus would not require major adjustments in the labor force. If the proportions women comprise of each occupational group remain at 1964 levels, the changing occupational requirements for all workers would result in a 32-percent increase in employment of women workers—from 24.2 million in 1964 to 32 million in 1975. This represents an average annual rate of increase over the 1964–75 period which is nearly the same as that of the 1958–64 period. However, it does reflect a narrowing of the recent differential in growth rates between women and men workers—from 2.2:1 during the 1958–64 period to 1.4:1 in the 1964–75 period. Nevertheless, the proportion women make up of total employment would rise from about 34 percent in 1964 to 36 percent in 1975. Rapid increases in some occupations in which large numbers of women are employed, such as clerical and sales, would be partially offset by slower-than-average growth in private household workers—nearly all women—and declines in farm workers.

If the proportion of women in each occupation were to continue to increase at the 1958–64 rate (rather than remain at the 1964 level), the results would not be much different, since only small increases in the proportion took place during this past period. On this basis, employment of women would be only about 900,000 higher than if the rates were to remain at 1964 levels—a difference of less than 3 percent. Similarly, the proportion women represent of total employment would be only slightly higher—37 percent as compared with 36 percent, as table 12 shows.

TABLE 12. SEX DISTRIBUTION OF 1964 EMPLOYMENT AND HYPOTHETICAL 1975 REQUIREMENTS

[In millions]

Sex distribution	Actual 1964		Hypothetical, 1975: Based on 1964 proportions		Hypothetical, 1975: Based on 1958–64 trends in proportions	
	Number	Percent	Number	Percent	Number	Percent
Total, male and female	70.4	100	88.7	100	88.7	100
Male	46.1	66	56.7	64	55.8	63
Female	24.2	34	32.0	36	32.9	37

A comparison of the hypothetical 1975 estimates of employment of women with projections of the civilian labor force in 1975 [91] further indicates that employment opportunities for women workers in the years ahead will not be significantly altered by the changes in occupational requirements. As table 13 shows, requirements for women workers in 1975 (expressed as a proportion of total requirements) will be roughly the same as the supply of women workers (expressed as a proportion of total civilian labor force), whether the proportions of women workers remain at the 1964 level or increase as they did in the 1958–64 period. However, this

[91] Based on "Labor Force Projections for 1970–80," *Monthly Labor Review*, February 1965.

overall balance does not allow for possible differences in age, education, training, etc., between the women workers required and those available. As the earlier sections of Part V on color and age showed, there may be significant differences in 1975 in the demand and supply of all workers by color and age. Thus, despite the overall balance of requirements and supply of women workers in 1975, the same adjustment problems as to age and color may exist for women as for the labor force as a whole.

Furthermore, there may have to be some additional shifts in the occupational distribution of female employment. The increasing competition with men is a very serious problem, as more and more men compete for jobs in occupations in which women have long predominated, such as elementary and secondary school teaching, social work, and library work. In order to maintain the projected rate of growth in employment, women workers must find employment outside the traditional women's occupations, particularly in the managerial, technical, and professional fields.

TABLE 13. SEX DISTRIBUTION OF PROJECTED CIVILIAN LABOR FORCE AND HYPOTHETICAL 1975 OCCUPATIONAL REQUIREMENTS

Sex distribution	1975 civilian labor force	Hypothetical 1975 requirements	
		Based on 1964 proportions	Based on 1958–64 trends in proportions
Total	100	100	100
Male	63	64	63
Female	37	36	37

APPENDIX TABLES

APPENDIX TABLE A–1. EMPLOYMENT IN 1964 AND PROJECTIONS OF EMPLOYMENT REQUIREMENTS IN 1975 UNDER AN ASSUMPTION OF 3 PERCENT UNEMPLOYMENT

[In thousands]

Employment	Actual 1964 employment	Projected 1975 requirements
Total labor force	76,971	94,100
Less: Armed Forces	2,738	2,700
Civilian labor force	74,233	91,400
Less: Unemployment (3 percent assumed in 1975)	3,876	2,740
Civilian employment	70,357	88,660
Less: Agricultural employment	4,761	3,745
Nonagricultural employment	65,596	84,915
Less: Nonagricultural self-employed workers	6,266	7,420
Nonagricultural unpaid family workers	594	865
Domestics	2,621	3,240
Nonagricultural wage and salary employees, other than in households	56,115	73,390
Difference between count of jobs and count of people [1]	2,041	2,485
Employees in nonagricultural establishments (based on payroll reports)	58,156	75,875

[1] Most of 2 million difference between the household and nonfarm establishment surveys can be explained by conceptual differences in the 2 series. There were an estimated 3.1 million dual jobholders in May 1964, whose secondary jobs are reflected in the payroll count but not in the household data. Partly offsetting this difference were about 900,000 employees on unpaid absences—not counted in the payroll series but included as employed in the household series. The remaining difference would be accounted for mainly by the misclassification in the household survey of some officers of small corporate enterprises as self-employed rather than as wage and salary employees.

APPENDIX TABLE A–2. EMPLOYMENT OF NONAGRICULTURAL WAGE AND SALARY WORKERS, BY INDUSTRY, 1964, AND PROJECTED REQUIREMENTS, 1975 [1]

[In thousands]

	Actual 1964 employment	Projected 1975 requirements	Percent change
Total	58,156	75,875	30
Mining	633	620	(2)
Contract construction	3,056	4,190	37
Manufacturing	17,259	19,740	14
Durable goods	9,813	11,500	17
Ordnance and accessories	247	250	(2)
Lumber and wood products, except furniture	603	550	−9
Furniture and fixtures	406	510	26
Stone, clay, and glass products	612	675	10
Primary metal industries	1,231	1,290	5
Fabricated metal products	1,187	1,460	23
Machinery	1,606	2,050	28
Electrical equipment and supplies	1,548	2,000	29
Transportation equipment	1,605	1,730	8
Motor vehicles and equipment	755	800	6
Aircraft and parts	604	575	−5
Instruments and related products	369	510	38
Miscellaneous manufacturing industries	399	475	19
Nondurable goods	7,446	8,240	11
Food and kindred products	1,746	1,665	−5
Tobacco manufacturers	89	80	−10
Textile-mill products	891	880	(2)
Apparel and related products	1,302	1,525	17
Paper and allied products	625	775	24
Printing, publishing, and allied products	951	1,100	16
Chemicals and allied products	877	1,125	28
Petroleum refining and related industries	183	160	−13
Rubber and miscellaneous plastic products	434	580	34
Leather and leather products	348	350	(2)
Transportation and public utilities	3,947	4,425	12
Trade, wholesale and retail	12,132	16,150	33
Finance, insurance, and real estate	2,964	3,725	26
Services and miscellaneous	8,569	12,275	43
Total government	9,595	14,750	54
Federal government	2,348	2,525	8
State and local government	7,248	12,225	69

[1] Projections assume an unemployment rate of 3 percent in 1975.
[2] Less than 3 percent.

NOTE: Because of rounding, sums of individual items may not equal totals.

EMPLOYMENT, OUTPUT, AND POLICY REQUIREMENTS FOR FULL EMPLOYMENT

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CONTENTS

Employment, Output, and Policy Requirements For Full Employment

Introductory Note

A major revision was made to the official national income statistics after the present study had been completed. It was not possible to redo the whole analysis on the basis of the revised data since none of them were available until this report had been drafted. Moreover, all of the needed data will not be available for some time. No doubt many specific estimates presented here would be somewhat different if the revised data could be used at every stage. However, it appears that the primary conclusions and policy recommendations presented below would not be changed importantly.

A part of the revision in the national income statistics has been incorporated into this report. For 1962 and earlier years, the old GNP statistics are used. But the GNP *increases* since 1962 are taken from the revised data. Thus, while the analysis and projections are based on the old historical series, the better statistical estimates now available for the 1963–65 period are used to measure GNP growth during that time. This procedure should approximate what a regular annual revision of the statistics would have shown for the most recent years on the basis of the old historical series. The relation among the different series is as follows:

GNP

[In billions]

	1962	*1963*	*1964*	*1965, 2d quarter*
Old series	$556.2	$583.9	$622.6	$658.0
Revised series	560.3	589.2	628.7	665.9
Series used here	556.2	585.1	624.6	661.8

Summary

This report analyzes the employment gains that will be needed to achieve full employment of the labor force in the years ahead, the expansion of demand and output that will be necessary to create the needed employment opportunities, and the Government economic policies that will be necessary to bring forth the required expansion of demand and output. The analysis centers on a 3½-percent unemployment rate as an interim definition of full employment. This definition is chosen because it lies sufficiently far ahead to be a useful target and yet appears to be attainable without overextending the economy's industrial capacity or encountering prohibitive shortages of suitably trained labor. The implications of a 3-percent unemployment target are also examined briefly, though the estimates in this case are far more conjectural. The analysis is concerned mainly with the economy under expected normal future conditions; the special circumstances of the Vietnam war are treated as a temporary departure from the main assumptions.

Despite the rapid output gains of the past 2 years which have lowered the unemployment rate below 4½ percent, expansionary fiscal measures will be required in the immediate future in order to achieve full employment and to maintain it, once achieved. The impact of the 1964 tax cuts on the unemployment rate has been realized already. And we are just entering the period of most rapid increases in the labor force. Unless future employment gains are accompanied by slower productivity improvements than past experience suggests, total demand and production will have to accelerate if full employment is to be achieved.

To bring the unemployment rate to 3½ percent by the start of 1968, employment will have to ex-

pand by 4½ million in the 2½ years starting with the third quarter of 1965. To create this many jobs, GNP will have to increase to an estimated $809 billion in the first quarter of 1968. Thus, from a projected $684 billion GNP in this year's fourth quarter ($688 billion in the revised data), GNP gains from then until the first quarter of 1968 would have to average $14 billion per quarter. This compares with average gains of $10.5 billion experienced in the six quarters since the 1964 tax cuts took effect.

A median estimate of the Federal fiscal policies needed to achieve this output and, hence, these employment goals is a 5-percent annual increase in Federal purchases of goods and services—a $10 billion increase between 1965 and 1968—together with a 13-percent personal income tax cut ($7 billion valued at 1965 income levels) effective by the end of 1966. This is just one policy combination that would provide the needed stimulus, and it could involve a wide range of specific programs. Alternative policy measures having an equivalent fiscal stimulus are discussed below. (With any of these, it should be noted that total Federal expenditures will rise by considerably more than the specified increase in Federal purchases. Transfer payments to individuals, businesses, and other levels of government will be increasing. Unlike Federal purchases, these transfers do not directly generate a demand for labor; and they augment total income only to the extent that they are not matched by equivalent increases in Federal revenues. Taxes and transfer expenditures under presently scheduled programs, such as the excise tax cuts, Medicare, and grants to State and local governments have been accounted for in the estimate of future policy requirements, with Federal expenditures other than purchases projected to increase by $14 billion between 1965 and 1968. (The indicated changes in Federal purchases and taxes are in addition to these.) In 1968, a $3½ billion deficit is projected for the Federal budget in the national income accounts with the policy steps described above.

Underlying the median estimate of policy needs are two alternative projections of future private investment demands. Neither projection suggests a need for reducing corporate-profits taxes. However, it is assumed that an expansion of money and credit will occur sufficient to accommodate the 7.4 percent annual increase in GNP between 1965 and 1968 without sharply higher long-term interest rates than prevail at present.

In order to achieve the 3½-percent unemployment goal a year earlier, by the start of 1967, earlier fiscal stimulus would be required. A large defense buildup in connection with the Vietnam war is a realistic context in which to examine this possibility. If, by the start of 1967, there is an increase of 300,000 in the Armed Forces together with a $10-billion increase from recent levels in the rate of Federal purchases for defense, no additional fiscal stimulus would be needed to reach full employment by 1967.

Reaching a 3-percent unemployment target would require an estimated further stimulus equivalent to $4 billion of additional Federal purchases superimposed on any of the policy combinations that would achieve a 3½-percent unemployment rate. However, this and other estimates associated with 3-percent unemployment are necessarily quite uncertain from this distance.

Whatever the unemployment target, once it is achieved, output and employment will grow less rapidly. Eventually, investment demands can be expected to slacken and further fiscal stimulus will be required to maintain full employment in subsequent years.

Inflation is not expected to pose a prohibitive conflict with a 3½-percent unemployment target. A 2- to 2½-percent annual increase in the GNP price deflator is projected in this case, only moderately above the rate of increase in recent years. The Consumer Price Index would advance at about the same rate as the GNP deflator and average wholesale prices, perhaps one-half a percentage point slower. With a 3-percent unemployment rate, the threat of considerably more price pressures exists. These can be assessed far better once experience is available with the 4-percent rate; but from now, projected increases of 3 to 4 percent a year in each of the three price measures seem likely for the 3-percent unemployment economy of the future.

The 3½-Percent Unemployment Goal

Employment

Table 1 summarizes the estimated employment increases required to reach a 3½-percent unemployment rate by 1968 and to maintain that rate in subsequent years. The increases in total employment are based on projections of total labor force growth made by the Bureau of Labor Statistics and econometric estimates of the relation between labor-force participation rates and unemployment. In projecting the employment breakdown, the minor categories of military, agriculture, and civilian Government employment are projected separately. This leaves the balance of the needed employment increase in the private nonagricultural sector, all of which is projected for nonfarm businesses. The employment breakdown arrived at in this way is consistent with the productivity and total output projections discussed below. However, the total output projections are not highly sensitive to the breakdown given here.

The extremely rapid employment increases during the 1965–68 period arise from the need both to create 4 million civilian jobs for the projected increase in the potential labor force between these years and to create jobs for an estimated additional 1.5 million workers who would have been employed in 1965 had the unemployment rate been at 3½ percent throughout that year with the labor force at its corresponding potential level. The employment gains after 1968 reflect only the jobs needed for the expanding labor force, since 3½ percent unemployment is assumed to prevail in all subsequent years.

Output and Productivity

The output gains needed to create the jobs outlined in the previous section will depend on the changes that occur in output per man, which in turn will depend on developments in man-hour productivity and changes in average hours worked. As the unemployment rate falls in the projection period, output per man is expected to continue to expand faster than its trend rate. Between 1965 and 1968, output per man in the private nonagricultural sector is projected to rise by 2.6 percent per year, and by 2.35 percent per year thereafter.[1]

Table 2 gives the projections of GNP resulting from these calculations. These are the current dollar values of total output needed to achieve and maintain a 3½-percent unemployment rate starting in 1968. Real output requirements have been converted to current-dollar GNP requirements by projecting a 2-percent average annual increase in the prices ~~of~~ all final outputs. This rate of increase in the GNP price deflator is about one-half a percentage point above that experienced in recent years; it reflects the smallest change that can be expected in light of the higher utilization rates and lower unemployment in the projection years.

The GNP projections may be analyzed with reference to the concepts of potential output and the output gap. Defining potential output as the GNP that would prevail with a 3½-percent unemployment rate, the output gap at any time is defined as the difference between potential and actual GNP. The gap estimated for 1963 is $34 billion, or 5.7 percent of actual 1963 GNP. For

TABLE 1. ACTUAL AND PROJECTED EMPLOYMENT ASSUMING 3½ PERCENT UNEMPLOYMENT IN 1968 AND SUBSEQUENT YEARS

Type of employment	Employment (in millions)							Average annual percent changes			
	Actual			Anticipated	Projected						
	1955	1956	1964	1965	1968	1975	1980	1956–64	1965–68	1968–75	1975–80
Total civilian employment	63.2	65.0	70.4	72.1	77.6	87.8	95.3	1.0	2.5	1.7	1.7
Private nonagricultural employment	49.7	51.5	56.2	57.8	62.6	70.1	74.7	1.1	2.7	1.6	1.3
Nonfarm business employment	41.0	42.6	46.8	48.4	53.2	60.7	65.3	1.2	3.2	1.9	1.5
Agricultural employment	6.7	6.6	4.8	4.6	4.0	3.0	2.5	−3.9	−4.0	−4.0	−4.0
Government employment	6.8	6.9	9.4	9.8	11.0	14.7	18.1	3.9	4.2	4.2	4.2

[1] Throughout, output per man in agriculture rises by 5 percent a year and remains unchanged in the Government sector owing to the convention by which Government output is measured by the labor input used.

1964 it is $31 billion, or 4.9 percent of GNP. And for 1965, the gap expected on the basis of a $668 billion GNP for the year ($672 billion in the revised data) is $23 billion, or 3.5 percent of the projected GNP.

TABLE 2. ACTUAL AND PROJECTED GROSS NATIONAL PRODUCT ASSUMING 3½ PERCENT UNEMPLOYMENT IN 1968 AND SUBSEQUENT YEARS

[In billions]

Gross national product	Actual			Anticipated		Projected			
	1956	1961	1964	1965	4th qtr. 1965	1st qtr. 1968	1968	1975	1980
Gross national product—current prices	$419	$519	$625	$668	$6[illegible]	$809	$828	$1,259	$1,692

	Average percent change per year					
	1956–61	1961–64	4th qtr. 1965–1st qtr. 1968	1965–68	1968–75	1975–80
Gross national product—current prices	4.4	6.4	7.8	7.4	6.2	6.1
Gross national product—constant prices (total real output)	2.3	4.9	5.7	5.3	4.1	4.0

As in the case of the employment projections, the rapid GNP gains required between 1965 and 1968 reflect the need both to close the present output gap and to keep pace with the growth in potential GNP between now and 1968. With potential GNP growing at an average of $45 billion per year between 1965 and 1968, actual GNP gains in 1966 and 1967 will have to average $14 billion per quarter starting from a projected GNP of $684 billion in the fourth quarter of 1965 ($688 billion in the revised data). This compares with average gains of $10½ billion in the six quarters since the 1964 tax cuts. In terms of total real output (GNP adjusted for price changes), the 5.7 percent annual rate of increase needed between the end of 1965 and the start of 1968 compares with a 4.7-percent annual rate of increase since the tax cut.

With 3½-percent unemployment achieved by 1968, more modest GNP gains will be sufficient thereafter to create the needed expansion of jobs. Between 1968 and 1975, GNP increases averaging 6.2 percent a year should maintain a 3½-percent unemployment rate. These would represent increases in total real output of 4.1 percent a year and in private nonfarm real output of about 4.0 percent a year. Even these increases are substantially faster than those achieved between 1956 and 1964, when total real output grew at an average annual rate of 3.2 percent and private nonfarm output grew only slightly faster.

Policies

With the necessary output targets now specified, it is possible to examine what Government economic policies will be necessary to achieve these targets and their associated employment goals. Presently scheduled Government programs are taken as given and the policies discussed are in addition to these. The presently scheduled programs assumed in this way are (all figures at annual rates):

1. Net reductions of excise taxes of $1.7 billion in the second half of 1965, with further reductions reaching a total of $5.3 billion by 1969.

2. Payroll tax increases, including employers' and individuals' shares, of $5.1 billion in the first half of 1966, with further increases reaching a total of $11.4 billion by 1969.

3. Increases in social insurance benefits of $2.0 billion in the second half of 1965 (plus a one-time increase of $3.2 billion in the third quarter of 1965), with further increases reaching a total of $9.5 billion in 1969.

In addition, Federal grants-in-aid to State and local governments are assumed to increase by 9 percent each year to a level of $17.4 billion in 1970. Together with a 7½-percent annual increase assumed for State and local revenues from personal, corporate, and indirect business taxes, this matches a projected increase of 8 percent a year in State and local government purchases of goods and services. (One of the policy alternatives discussed below adds further to Federal grants-in-aid and, hence, to State and local purchases.)

Altogether, Federal expenditures other than purchases of goods and services are projected to increase by $14 billion between 1965 and 1968. This increase in Federal transfer expenditures arises from the projected growth in grants-in-aid to other levels of Government, expanded transfer payments to individuals through the Government's social insurance trust funds, and increased interest payments.

Unlike Federal purchases, which do both, these transfer expenditures augment incomes and revenues of other spending units in the economy but do not directly generate a demand for labor. In the projection period, their impact on total income is more than offset by the projected increase in total Federal revenues that would occur in moving to full employment by 1968. In the absence of tax changes other than those now scheduled, Federal revenues at full employment in 1968 are projected at $152½ billion (national income accounts basis). If Federal purchases of goods and services are held at present levels, total Federal expenditures in 1968 would be $137½ billion under the indicated growth of Federal transfers, leaving a $15 billion full employment surplus in the Federal budget. The present analysis indicates that full employment is not attainable under these circumstances.

The additional policy steps needed to achieve full employment are estimated using two alternative assumptions about future business investment demands. The analysis underlying these investment projections is based on capital stock and capital stock retirement estimates constructed for this report. The two projections are believed to span the likely developments in private investment demands in the 3½ percent unemployment economy of the future. Each estimate of investment demand, in turn, permits an estimate of total demands and the policies needed to achieve the output and employment goals outlined above. An average of the policy requirements indicated by each of the two assumptions is presented here as the best current estimate of future policy requirements.

The range between the high and low investment projections is considerable. For the full employment economy of 1968, with the high projection, investment demand is 10.2 percent of GNP and with the low projection, 8.6 percent. The range amounts to $6.6 billion on either side of the midpoint of 9.4 percent that is taken as the best present estimate. This is an indication of the inherent uncertainty that must surround such projections.

Both the higher and lower investment projections are based on expected growth in the stock of fixed business capital relative to employment and output that is greater than that experienced in the 1955–64 period. Such projections assume that future financial factors will be more favorable to investment than were those in the past period. The tax incentives of 1962 and 1964 are two reasons. The other important one is the assumption that future borrowing costs will not rise sharply from present levels as they did after the mid-1950's.

Corporate Tax Reduction. The question of corporate profits tax reduction or similar investment incentives is explored by comparing projected nonfarm business investment demands with projected retained corporate cash flows, defined as retained earnings plus corporate capital consumption allowances. Under either of the two investment projections, the ratio of retained corporate cash flows to nonfarm business fixed investment is adequate in comparison with the ratios that prevailed in 1955–56, the last comparable period. Under the higher investment projection, the ratio is 0.76 in 1968, 0.78 in 1970, reaching 0.83 in 1972, and remaining at near this level thereafter. Under the lower investment projection, the ratio is 0.92 in 1968; it reaches 1.00 in 1970 and continues rising sharply thereafter. For the average of the two projections, the ratio is 0.84 for 1968 and 0.89 for 1970, rising sharply thereafter. By comparison, the average for 1955–56 was 0.75.[2]

Further tax benefits resulting in greater cash flows and higher rates of return would lead to higher investment levels, particularly if the benefits took the form of specific investment incentives. For this reason, whether a need exists for further business tax benefits cannot be said until the desired rate of investment has been specified. However, in the projected circumstances of historically ample cash flows at full employment, the expected response from further tax benefits, while positive, is likely to be small. Therefore, if full employment is the main goal, the need for future fiscal stimulus appears to be in the direction of creating markets through higher consumer and Government demands, rather than creating capacity to satisfy already adequate demands from noninvestment sectors.

Policy Requirements

The kinds of fiscal measures needed to achieve and maintain full employment in future years are shown in table 3. For simplicity, the table summarizes the needed stimulus as a dollar amount of typical income tax reduction with two alternative growth rates in Federal Government purchases of goods and services. Below, various alternative policy measures having a comparable effect on employment will be discussed.

Under the first assumption, table 3 shows that if Federal Government purchases rise by 5 percent a year to $76 billion in 1968, a 13-percent tax reduction ($7 billion at 1965 income levels) would be needed starting in mid-1966 to achieve 3½-percent unemployment by 1968. These first years are characterized by exceptional investment demands as plant and equipment is added rapidly to keep pace with the expansion in output and employment. By the early 1970's, most of the catching up in the capital stock is completed. In addition to the continuing 5-percent annual rise in Federal purchases in each future year, additional stimulus, estimated at a further 15-percent tax reduction ($10 billion valued at 1970 income levels), is necessary to make up for the lower investment demands expected in subsequent years.

Under the second assumption, table 3 indicates how much larger the tax stimulus must be if Federal Government purchases rise more slowly. As in the 1963 to 1965 period, when the impact of a totally successful tax reduction was partially offset by the failure of Federal purchases to rise in

[2] The recent data revisions appear to strengthen this conclusion, raising cash flows relative to investment more in recent years than in the mid-1950's. This change would probably work in the same direction in the full employment projections, although without redoing the entire analysis with the new data, this is not certain.

step with potential GNP (at least until the defense buildup), the tax reductions shown for mid-1966 would be inadequate if Federal Government purchases rose by only 2 percent per year.

TABLE 3. FISCAL MEASURES NEEDED TO ACHIEVE AND MAINTAIN FULL EMPLOYMENT[1]

Alternative assumptions	Income tax reductions needed in mid-1966 to achieve 3½% unemployment by 1968 (at 1965 income levels)	Additional income tax reductions needed after 1970 to sustain 3½% unemployment (at expected 1970 income levels)
If Federal Government purchases rise 5 percent each year (from $65½ billion anticipated for 1965 to $76 billion in 1968, and $107 billion in 1975).	$6.8 billion or 12.7 percent	$9.9 billion or 15.0 percent
If Federal Government purchases rise 2 percent each year (to $69½ billion in 1968 and to $80 billion in 1975).	$12.2 billion or 22.9 percent	$16.5 billion or 28.2 percent

[1] See discussion under policy requirements.

Looking beyond the early 1970's, a need for further tax reduction is likely to arise even with a continuing 5-percent annual increase in Federal purchases. It is almost certain to arise in the projection with only 2-percent annual increases. But the uncertainty surrounding such distant periods is very large. After 1975, somewhat slower growth in the labor force and potential output are expected. This suggests that a slower rate of capital formation will be needed and the rate of net investment will decline. This decline may be reinforced by lower replacement demands for structures, echoing the long depression in new construction that started after the 1920's. But the force of these factors and the extent to which they will be offset by other developments is hard to estimate. In particular, the abundant cash flows cited earlier eventually should have the effect of stimulating investment or, through higher dividend payments, raising personal incomes and consumption. Some such effects may operate to sustain private demands above the levels now predicted even in the early 1970's. As that time approaches, far better estimates can be made.

Finally, the uncertainty surrounding even the 1968 projections should be mentioned again. The range of the alternative investment projections translates approximately into an unemployment range between 3.0 and 4.0 percent. Unless the costs of overshooting are different from the costs of falling short, policies conceived today can do no better than to aim at the middle of the range. Subsequent adjustments in policy are not difficult to make.

Alternative Forms of Stimulus. Policy requirements have thus far been presented in terms of general personal income tax reductions combined with two alternative growth rates for Federal Government purchases of goods and services. A wide range of specific programs could be included within these totals, with negligible differences in fiscal impact. And fiscal measures of a somewhat different nature, affecting Government transfers or specific forms of taxes, could be substituted with only small differences in their impact on employment and output. Therefore the choices among such alternatives should clearly be made on other criteria, such as their distribution of benefits within the population, the need for specific programs, and the desired composition of total output between public services or investments and private consumption. What is important for employment and output is that their total fiscal impact be sufficient.

Following are some examples of the range of policy alternatives that can be used, with an indication of the differences that could be expected in their fiscal impact.

1. Social insurance tax reduction could be used in place of general personal income tax reduction. (General revenues could be used to offset the loss of receipts by the social insurance trust funds.) If the reductions were confined to the individual contributions to the trust funds, their economic impact might be slightly larger than that of general income tax reduction because of their greater relative relief to low-income taxpayers. At one extreme, tax relief would be extended to low-income groups which presently pay no income tax but are subject to social insurance taxes and to indirect taxes from all levels of Government. If the reductions included employer's contributions as well, they would in addition have the desirable effect of lowering business costs, but would have a less certain impact on output and employment per dollar of tax reduction.

2. Selective forms of income tax reduction could be used in place of general rate reductions. Of the many possibilities, the range of their economic impact may be illustrated by two examples.

   a. Most potent in its economic impact and most focused on relief to low-income groups would be an extension of the income tax scale into the negative tax range. This might achieve the same economic impact with perhaps 10 percent less revenue loss than a general income tax reduction.

   b. An increase in the size of personal exemptions would have an economic impact comparable to general income tax reduction.

3. Higher levels of Federal Government purchases would have about an 8-percent larger impact on output and employment than the same amount of general income tax reduction. An $84

4

billion level of Federal purchases in 1968 would achieve the 3½-percent unemployment target without tax reductions.

4. Larger Federal grants to State and local governments would have the same impact as larger Federal purchases if they enlarged State and local spending by their full amount. However, to some extent, they may substitute for other State-local revenue sources without enlarging spending, in which case they would have the impact of various forms of tax reduction. Unrestricted Federal grants, which are not tied to particular spending programs or uses, have recently received attention as a means of financing needed expenditures while limiting the growing use of indirect taxes. On balance, these might be expected to have an eventual impact on output and employment not significantly different from general income tax reductions.

5. Expanded transfer payments to persons are formally equivalent to negative taxes. However, owing to the concentration of benefits among lower income groups that most transfer programs would involve, their impact on output and employment could be slightly higher than that of general income tax reduction. (If existing trust funds were used, general revenues could again be used to replenish the trust funds.)

The Composition of Output. The kinds of policy changes that are chosen for providing fiscal stimulus will affect the composition of final output. Table 4 gives a breakdown of the likely composition of output in the 3½-percent unemployment economy of 1968 under some alternative policy combinations. It also compares these 1968 projections with the 1955–56 period, the last time that low unemployment rates were experienced.

The policy A profile shown in the first column of the table illustrates why the achievement of full employment will require substantial fiscal stimulus. With the policies indicated for that profile, business-fixed investment would have to total an estimated 11.1 percent of GNP for 3½-percent unemployment to be attained. This is far higher than the investment demand actually expected, and policies are needed to expand other demands accordingly.

The policy B, C, and D profiles all illustrate alternative compositions of full employment GNP that are attainable. Comparing them with the actual experience of 1955–56 illustrates the major changes that will have evolved in the composition of output.

The mean estimate of business-fixed investment demands in the 3½-percent unemployment economy of the late 1960's is 9.4 percent of GNP. This is about 1 percentage point below the 10.3 percent of the 1955–56 GNP devoted to business-fixed investment. Other significant changes from the earlier period are the much larger share of State and local government purchases and the far smaller share of Federal purchases, even under the policy D profile which assumes they are increased to $80 billion by 1968. In all but the policy D profile, more of GNP is devoted to consumption in the 1968 projections; and in all profiles, con-

TABLE 4. THE 1968 ECONOMY AT 3½ PERCENT UNEMPLOYMENT UNDER ALTERNATIVE POLICY MEASURES

Item	A		Successful policies						Average of actual 1955–56 economies	
			B		C		D			
	In billions	Percent of GNP	In billions	Percent of GNP	In billions	Percent of GNP	In billions	Percent of GNP	In billions	Percent of GNP
Gross national product	$828	100.0	$828	100.0	$828	100.0	$828	100.0	$408	100.0
Residential construction	33	4.0	33		33		33			
Inventory accumulation	6	.7	6	5.7	6	5.7	6	5.7	25	6.2
Net exports	8	1.0	8		8		8			
State and local government purchases	86	10.4	86	10.4	86	10.4	88	10.6	32	7.8
Federal Government purchases	70	8.4	70	8.4	76	9.2	80	9.7	46	11.1
Business-fixed investment	92	11.1	78	9.4	78	9.4	78	9.4	42	10.3
Consumption	533	64.4	547	66.1	541	65.3	535	64.6	263	64.5
Disposable personal income	573	69.2	588	71.0	582	70.3	575	69.5	284	69.5
Corporate profits after taxes	45	5.5	45	5.5	45	5.5	45	5.5	23	5.7

Policies: A—*Slow rise in Federal purchases; no tax cuts.* Indicated GNP not attainable because indicated level of business-fixed investment is far greater than analysis predicts will occur. Federal policy keeps present income tax rates and increases Federal purchases of goods and services by 2 percent a year to levels shown. Presently scheduled changes in other tax and transfer programs assumed to occur as described in text (including a 9 percent a year increase in grants to State and local governments).

B—*Slow rise in Federal purchases; large tax cuts.* Required stimulus to reach 3½-percent unemployment provided entirely through a 23-percent reduction of personal income taxes ($12 billion reduction at 1965 income levels). Other programs as in A.

C—*Larger increase in Federal purchases; moderate tax cuts.* Required stimulus provided through a combination of faster increase in Federal purchases of goods and services, which rise 5 percent each year to level shown, and a 13-percent reduction in personal income taxes ($7 billion at 1965 income levels). Other programs as in A.

D—*Large increase in Federal purchases; new Federal grants to State and local governments; no tax cuts.* Required stimulus provided through (1) a rise in Federal purchases of goods and services by $4 billion more than the 5-percent annual rise used in C; (2) an increase in untied grants to State and local governments of $4 billion in addition to the 9-percent annual rise in Federal grants assumed in A, half of these untied grants assumed to expand State and local government purchases and half to reduce State and local taxes. Other programs as in A.

sumption plus total Government purchases are greater than they were in 1956.

A present projection of the 3½-percent unemployment economy in the 1970's would show a smaller fraction of GNP going to business-fixed investment. The deficiency of business structures and equipment will have been made up by the high investments of the late 1960's, prompted by the rapid rise of GNP to its potential level. Subsequently, for at least an interim period, investment spending would be expected to rise less rapidly.

The Federal Budget. The policies needed to reach full employment imply a small deficit in the Federal budget projected for 1968. Using the policy C profile described in table 4, projected Federal receipts and expenditures on a national income accounts basis are shown below in table 5, together with the expenditures expected for 1965.

TABLE 5. FEDERAL BUDGET IN THE NATIONAL INCOME ACCOUNTS, 1965, AND PROJECTED 1968[1]

[In billions]

Budget	1968	1965
Total deficit	$3.5	
All expenditures	147.5	123.0
Purchases of goods and services	76.0	65.5
Personal and foreign transfers	44.0	34.0
Grants to State and local governments	14.5	11.5
Net interest paid	9.5	8.5
Subsidies less current surplus of government enterprises	3.5	3.5
All revenues	144.0	
Personal income taxes	58.0	
Corporate profits taxes	33.5	
Indirect business taxes	17.0	
Social insurance contributions	35.5	

[1] Assuming 3½-percent unemployment, using policy C. (See table 4.)

The 3½-Percent Goal by 1967

The discussion until now has assumed a 3½-percent unemployment target will be achieved by 1968. To advance the target date to 1967 would require an earlier fiscal stimulus. The longer run needs for sustaining 3½-percent unemployment in future years would be unchanged.

With good gains in output and employment now assured for 1965, a strong fiscal program started in the immediate future should be capable of achieving this goal. The enlarged defense activities associated with Vietnam will reduce the nondefense output and employment opportunities associated with potential GNP; similarly, they will reduce the fiscal stimulus required from civilian programs. Although the defense buildup is assumed to be temporary, it affords a realistic context in which to examine the possibility of reaching full employment by 1967.

If, by the start of 1967, there is an increase of 300,000 in the Armed Forces together with a $10 billion increase from recent levels in the rate of Federal purchases for defense, no additional fiscal stimulus would be needed to reach full employment by 1967. (Indeed, the present rate of business investment spending relative to GNP is larger than its equilibrium rate projected in this study. The present analysis indicates this is temporary; but should it continue throughout 1966, 3½-percent unemployment by 1967 would be consistent with a rise in the rate of defense purchases a few billion dollars smaller than indicated here.) Federal nondefense purchases of equal amount could be substituted for a part of this rise in defense purchases with equal effect on output and the unemployment rate.

Under these circumstances, the 3½-percent unemployment GNP projected for 1967 is $777 billion, $3 billion lower than the projection with the 2.7-million man Armed Forces expected for normal future years. From an anticipated $684 billion GNP in the fourth quarter of 1965 ($688 billion in the revised data), GNP gains of $14 billion will be needed in each of the following five quarters to achieve the target by 1967, with $12 billion quarterly gains needed during the remainder of 1967 to maintain a 3½-percent unemployment rate. When changing conditions permit a reduction in the Armed Forces and a cut in spending for defense, fiscal stimulus designed to expand civilian output will have to be introduced in line with the projections made earlier.

Prices

The GNP price deflator is projected to increase by 2 to 2½ percent yearly in the 3½-percent unemployment economy of the future. (The 2-percent rate of increase has been used in making the GNP projections in this paper.) The Consumer Price Index should rise at about the same rate while the corresponding increase in wholesale prices is expected to be about 1½ to 2 percent annually, reflecting the absence of service prices in this index. These moderate rates of price increase are somewhat slower than an analysis of the entire postwar period would suggest for low unemployment, high-profit conditions. However, our recent experience has been better than the postwar average. The widespread discussion of the administration's wage-price guideposts may be having a favorable impact in industries and labor markets where considerable discretionary power over wage and price decisions exists. And for the future, labor force policies designed to upgrade skills and basic educational accomplishments and to increase the mobility and adaptability of workers should reduce the cost pressures of lower unemployment rates. The 2- to 2½-percent rate of increase projected for the GNP deflator assumes continued efforts will be made in this area.

The 3-Percent Unemployment Goal

The characteristics of a 3-percent unemployment economy and the policies needed to achieve and maintain it are harder to estimate. The behavior of productivity, labor-force participation rates, average hours of work, business investment, and wages and prices that would accompany a move to 3-percent unemployment must all be inferred from a postwar history, lacking the appropriate direct observations. The estimates are necessarily speculative and subject to considerably wider error than those presented above. They may nonetheless offer some guidance for the future.

The discussion here will be in terms of reaching a 3-percent unemployment target by the start of 1970 after achieving 3½-percent unemployment by the start of 1968.

Increased labor-force participation rates at 3-percent unemployment are projected to expand the total labor force to 86.2 million in 1970, 200,000 above the level projected with 3½-percent unemployment in the same year. Projecting 2.7 million men in the Armed Forces as before, civilian employment will have to reach 81.0 million in 1970. Between 1968 and 1970, employment will have to rise by 3.4 million or by 2.2 percent per year. In order to achieve these employment goals total real output will have to rise by 4.7 percent a year.

The continuation of rapid output gains needed to achieve 3-percent unemployment should prolong the period of rapid increases in business investment into the 1970's, and might be expected to maintain the 1968 investment fraction of GNP in the 3-percent unemployment economy of 1970. Under these assumptions, this unemployment target requires a further stimulus equivalent to $4 billion of additional Federal purchases in 1970 superimposed on any of the policy alternatives shown in table 4 for achieving the 3½-percent unemployment goal. As in the earlier discussion, alternative policies involving different proportions of tax reduction and spending increases could be used.

The issue of sustaining 3-percent unemployment is parallel to the 3½-percent case. In the present projection, investment demands can be expected to slacken after output gains slow to the growth rate of potential output. This would require further fiscal stimulus to make up the deficiency by enlarging consumer or government demands.

Moving to a 3-percent unemployment rate would intensify inflationary pressures in the economy. Based on an analysis of the whole postwar period, the difference between 3- and 3½-percent unemployment could be expected to add at least 1 percentage point to the average annual rate of wage and price increases in manufacturing, with perhaps a smaller increment in most other sectors. However, the recent evidence of moderation in wage and price decisions suggests that this may be improved upon. In addition, the benefits of labor force policies, including training and education programs, should be felt most keenly as unemployment declines to lower levels and a larger fraction of all jobs go to the youngest and least skilled workers. All things considered, the GNP price deflator and indexes of consumer and wholesale prices are all projected to rise by 3 to 4 percent a year in the 3-percent unemployment economy of the future. With continued attention to price and wage decisions by the administration and expanding efforts in labor market policies and training programs, the lower of these does not seem unrealistic. However, further experience with lower unemployment rates than those prevailing at present would provide much more evidence on which to base a judgment.

Appropriate Goals for Policy

There is nothing that one can predict at this time with any conviction that should rule out a 3-percent unemployment target and the pursuit of fiscal policies capable of achieving it. And no lesser goal, achieved with more modest policies, will extend sufficient job opportunities to the most disadvantaged groups among whom unemployment is disproportionately concentrated.

There is no presumption that a high-employment economy is cyclically less stable than one with lower employment rates. Therefore, the desirability of any particular target can only be measured against the possible inequities arising from rapid inflation and any barriers that may arise from the Nation's balance-of-payments. The present projection of 3 to 4 percent yearly increases in the major price indexes at 3-percent unemployment is not clearly a deterrent on either ground.

It is generally agreed that quality changes are inadequately accounted for in most price indexes, so that these inflation rates represent a deterioration of real purchasing power perhaps only half as great. And, whatever the inequities of such a condition, they must be placed against the inequities of higher unemployment rates. This report has not attempted an analysis of the balance-of-payments situation in the future. But competitor nations will also be experiencing domestic price increases and the increases projected here are not clearly excessive.

Ultimately, these questions must be answered as they arise. There is no need to commit policy today to an irreversible course that may prove undesirable at some future date. The projections given here are necessarily uncertain, the more so the further they look into the future and the further they depart from present conditions in the economy. While they indicate that a 3-percent unemployment goal by at least 1970 is feasible and may be desirable, the first step should be policies to achieve an interim target of 3½-percent unemployment. This goal is achievable by 1967. The final decision on a lower unemployment target can be made with far better evidence once the first experience is available to us.

Part 2

THE TECHNOLOGICAL OUTLOOK

COMPUTER ASPECTS OF TECHNOLOGICAL CHANGE, AUTOMATION, AND ECONOMIC PROGRESS

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CONTENTS

Computer Aspects of Technological Change, Automation, and Economic Progress

I. Summary

This report surveys the important trends in the computer field and their implications for several specific industries, and discusses the social implications of the increasing penetration of computers into our daily lives.

It is clear that computers and information processing are destined to play a vital role in industry, commerce, agriculture, education, health, transportation, government, science, and technology. To paraphrase an advertising slogan, "There's a computer in your future." Computers will become much faster and smaller and computing power will become much less expensive. Computing power will be available in the same way that electricity and telephone service are today. As a consequence, information as a commodity will become less expensive and more readily available. The amount of raw computing power in the United States has been doubling every year, and the author believes that it will continue to grow at that rate during the next decade, although some computer specialists are more conservative.

As one consequence of these trends, the author believes that productivity will increase slightly faster in the next decade than in recent years. However, he rejects the view held by some that a small percent of the work force, aided by computers and automation, will produce a glut of goods and services; rather, he believes that full employment can be maintained. Increases in productivity, however, will often outpace demand in certain industries, displacing people from jobs. Society must look for ways to minimize the hardships of the displaced and to keep the economy growing at a rate so that they can find other jobs.

Computers and information processing are accelerating the overall pace of technological change. As the tempo of change increases, men must adopt the view that education is a continuing process throughout life. Men must devote more time to continuing their education; and society must develop means for providing the financial support.

The possible implications of information processing for banking and government are shown to be quite significant. In both cases, the factors which determine how fast these changes will come about are political and social, not economic or technological.

In a world in which information about people and organizations is centralized in computer files, the problem of privacy becomes an issue of major concern.

II. Introduction

> The art of progress is to preserve order amid change and to preserve change amid order.
> —Alfred North Whitehead

Scope and Limitations of the Study

This report consists of (1) a survey of important trends in the computer field; (2) a look at the implications of these trends for several specific industries; and (3) a discussion of the social implications of the increasing penetration of computers into our daily activities. Because of time limitations, these discussions rely mainly on the author's own experiences, discussions with experts, and readings of selected literature.

In the following pages, the terms "computing," "electronic data processing" (EDP), and "information processing" are used interchangeably. The last, and broader, term describes what the computer can actually do; i.e., the systems usually called computers can process many kinds of information besides carrying out arithmetic processes on numbers. Also, while this report in the main deals with computers and information processing, it also attempts to cover those instances of automation and technological change that are heavily dependent upon computers.

A distinction is often made between computers and automation, viz., that automation replaces man's muscular activity, while computers replace his mental activity. This distinction often does not hold since at times a mixture of both exists, as in the numerically controlled machine tool whose operation is controlled by a tape produced by a computer. However, social problems are much the same whether arising from computers, automation, or technological change.

This report does not cover all important applications of computers, since a number of areas of major utilization are dealt with in other studies for the Commission. This report should be read in conjunction with a companion report by Merrill M. Flood, "Commercial Information Processing Networks—Prospects and Problems in Perspective."[1] The development of such information processing networks is so important to the computer field that the Commission singled this topic out for special study.

Attitudes of the Author. In his excellent book *The Shape of Automation*,[2] Herbert A. Simon suggests that attitudes toward computers and their economic implications have two dimensions—technological and economic.

Like Simon, I am a technological radical and an economic conservative as he defines them, although in each case somewhat closer to the center. That is, with respect to technology, I believe that in time computers will be able to carry out any information processing task that men can do. However, I believe that many of the problems remaining to be solved are very difficult; i.e., I am not as optimistic as Simon, who foresees computers doing anything man can do, with only minor qualifications and reservations, in our time.

Economically, I reject the radical view that computers and automation, manned only by a small percentage of the available work force, will produce a glut of goods and services. Rather, I believe that although computers and automation will contribute to a somewhat accelerated rise in productivity, full employment can be maintained. I further believe that although mankind will find life in the future considerably different, both economically and socially, the change need not be traumatic.

This is not to suggest that I believe that computers and automation are not causing problems requiring economic, social, and political adjustments. They obviously are—and the problems are serious ones.

Some Problems of Measuring the Impact of Computers. Most of the attention given to the social implications of information processing technology focuses upon the effects of computers on employment. An assessment of these effects is quite difficult because many factors affecting the situation are changing at the same time. The number of employees in a computerized firm today can be compared with the number of employees prior to the introduction of a computer, but the analysis of the effect is complicated by changes in volume of business, different prices (and therefore different demand) for the firm's products and services, and often by quite different products and services. The interplay between computerization, cost, and demand is crucial to the ultimate effect of automation on employment.[3]

The effect of the introduction of new technology in one industry is often felt in another. For example, the declining cost of long-distance telephone calls and improved airmail service due to jet airplanes has had a serious negative impact on the telegraph industry.

[1] Merrill M. Flood, *Commercial Information Processing Networks—Prospects and Problems in Perspective*, A report prepared for the National Commission on Technology, Automation, and Economic Progress, 1966.

[2] Herbert A. Simon, *The Shape of Automation*, Harper & Row, New York, 1965.

[3] For an excellent discussion of the difficulties associated with measurement in this general area see Solomon Fabricant, *Measurement of Technological Change*, Seminar on Manpower Policy and Program, July 1965, Manpower Administration, Office of Manpower, Automation, and Training, U.S. Department of Labor, 1965.

III. Computer Trends

Computers Are Becoming Faster, Smaller, and Less Expensive

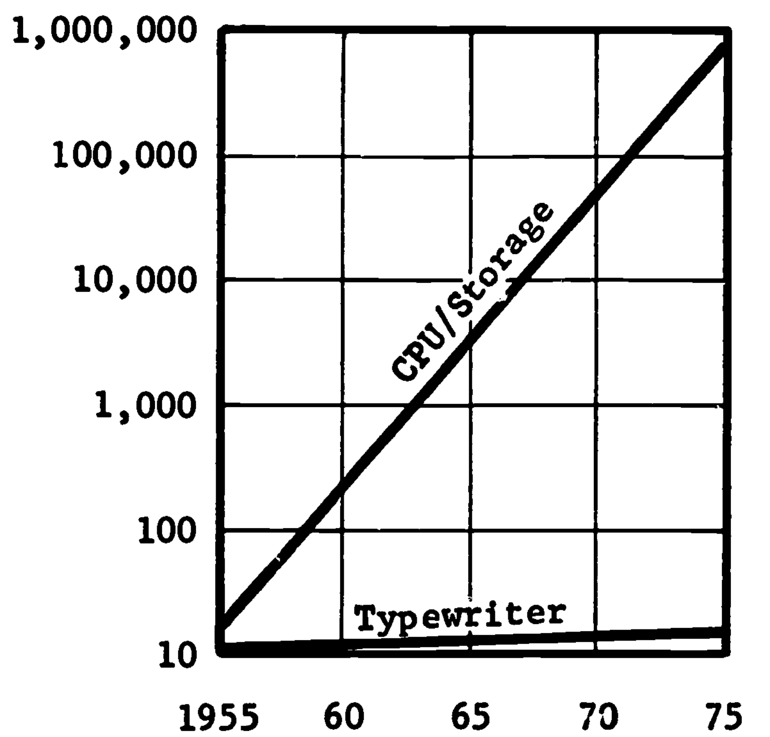
Basically, a computer consists of a unit (memory) for storing instructions and data, a central processing unit (CPU), and input/output (I/O) equipment for getting instructions and data in and processed results back out. In terms of this simplified concept, let us examine trends with respect to speed, size, and cost. To simplify matters further, central processors and storage units will be considered together in the following discussion since they are both dependent on electronics, while input/output devices are usually mechanical with a little electronics mixed in. For purposes of comparison, the typewriter can illustrate input/output. It is not necessarily typical, but will, I believe, become one of the most commonly used I/O devices of the future. Had magnetic tape, say, been chosen instead of the typewriter on figures 1, 2, and 3, it would have shown much greater increases in speed and decreases in cost than typewriters. The "size" curve (figure 2) for magnetic tape would be about as flat as for typewriters.

These graphs are merely intended to give a general impression of trends. In no case should the data be considered precise; not only have they been smoothed, but they are based on various assumptions regarding definitions not explicitly given in the text. Because speed, cost, and size are changing so rapidly, they have been plotted on a logarithmic scale; that is, each horizontal line represents a change by a factor of 10.

What are the implications of the information in these figures? With respect to speed, computers will be able to do more and more information processing in a given period of time. For applications involving a high percentage of input/output, speed increases will not be nearly as significant as for tasks with little input/output. However, a single CPU-storage combination will be able to serve many I/O units simultaneously.

The costs of CPU's and storage units are declining even as speeds increase; consequently, computing power is becoming very inexpensive. (Fig. 3 depicts the cost of computing power, not of computers.) Input/output costs will dominate other costs. As total costs continue to decline, computers will become commonplace and someday will be found in every factory, office, business establishment, classroom, airplane, car, and home, and eventually may be found on every person. (Rather than the computer itself being so located and available, it may be that the equivalent information processing capability will be available from a central source over a communications link.)

FIGURE 1.—*Speed* [1]



[1] CPU/storage speed in thousands of additions per second; typewriter speed in characters per second.

FIGURE 2.—*Size*

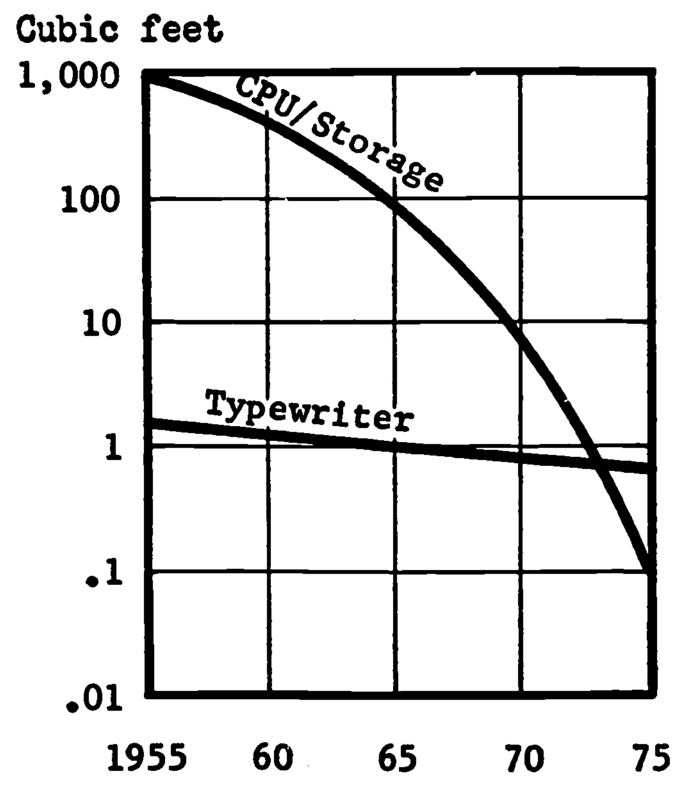
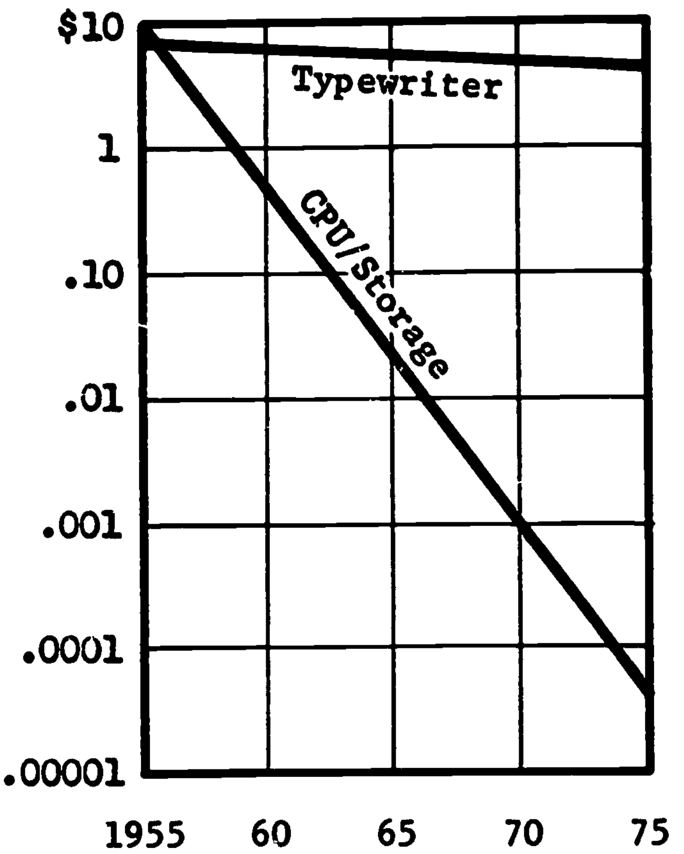


FIGURE 3.—*Cost*[1]



[1] CPU/storage cost in dollars per million additions; typewriter costs in dollars per million characters.

Physically, CPU's and storage units are getting very small. The size of the I/O unit will dominate; otherwise, very little volume will be required. It will be possible to install a computer on the back of a typewriter or under the dash of an automobile, or to carry one easily on one's person. Fast computers must be small in size, since the time devoted to the propagation of signals over wires inside a computer slows the system down.

Computing Power Will Become Available Much the Same as Electricity and Telephone Service Are Today[4]

Variously called information processing networks, information utilities, online time-shared systems, or computer utilities, such systems consist of a number of terminals (input/output devices—today usually a teletype unit or a modified typewriter) connected over communication links (the connection may be permanent or dialed up when needed) to a very high speed computer with a large storage capacity. The central computer devotes a very small period of time to each I/O device in turn. But because the speed of the central computer is so great, each user appears to be receiving the complete attention of the computer.

Computer utilities can be organized in several ways. Large firms may buy the computer system and install terminals within their plant or at branch offices. Multiplant firms may connect all terminals to a single large computer or have several decentralized computers which are connected together. The terminals of many small firms may be connected to the computer of an organization formed to serve those firms. The seller may be a computer service bureau, a commercial bank, a computer manufacturer, a communications supplier, or possibly a large, regulated public utility. Eventually, through the flexibility provided by an adequate communications network, a given terminal could be connected at will to any one of many information utilities.

The communications link introduces a new item into the total cost picture, raising the question that if computers are to become very inexpensive in the future, why not have the computer at hand rather than pay communication costs to a centralized facility? The answer is that over something like the next 5 years and possibly longer, the relative costs of computers and communications will be such that networks will exist in large numbers. As the cost of storage and CPU's continues to decline, however, it may become less expensive to install some processing and storage capability at the terminal, thus avoiding communication costs. However, at times it will undoubtedly be advantageous to have access to the large "centralized data banks" which will come into existence in the next decade, and thus considerable use will be made of communication links. Consequently, in the 1970's there will probably be much computing power at the terminal itself. The terminal will be connected, when necessary, over a communications network to a central computer system to make available even more computational ability and information of many kinds from large data files.

Information Itself Will Become Inexpensive and Readily Available

As a consequence of information processing becoming inexpensive, and with the existence of information-processing networks, information as a commodity will itself become inexpensive and readily available. For example, a man going from Los Angeles to Chicago on a business trip could quickly learn what flights (of all airlines) leave Los Angeles for Chicago after 5 p.m.; which motels are within 5 miles of the Chicago airport, and what their characteristics are; and biographical data and credit rating on individuals to be seen. A family needing a new refrigerator could readily get information on available models and might also consult *Consumer Reports* for their latest evaluation of refrigerators.

None of the above will be available next year, and even in 10 years some of it may not be truly inexpensive, but the trend is undeniable. While

[4] The importance of this development is such that it is the subject of a separate study for the Commission, see Flood, *op. cit.*

the 1964–65 New York World's Fair was in operation, anyone in the country with access to a teletype could dial a computer at the Fair and receive a short essay and/or a suggested up-to-date reading list of any one of 70 different topics.

Computers Will Become Easier To Use

Computers are capable of only a comparatively few basic operations—addition, subtraction, multiplication, division, comparison of words or numbers, etc. A list of basic instructions in proper sequence (the program) must be fed into a computer in order for it to do useful work. Early users learned that programing a computer is a difficult, time consuming, and expensive process, with the cost often exceeding that of the machine time. The most important development reducing this burden has been the introduction of so-called "higher level languages." Rather than writing out a detailed list of instructions in the language of the machine, the user writes the program in a richer language that considerably reduces the number of instructions he has to write and relieves him of concern over many details. The instructions in this higher level language are fed into the computer, and a program in the machine translates them into detailed instructions which the machine can then carry out. While such languages do relieve the user of having to know machine-level language and are extensively used today, they are highly stylized and somewhat difficult to learn. In the next decade, however, further improvements in higher level languages should result in their becoming much easier to learn and to use. For many applications they will permit a user who knows very little about computers to instruct the machine.

The "online" attribute of computer utilities will also make machines easier to use. "Online" means that interaction between user and machine is direct and takes place without perceivable delay. In the past, the delay has been usually at least an hour and more often a day.

Organizations Already Utilizing Computers Will Expand From Recordkeeping and Accounting Applications Into Management Science and Decisionmaking

The most talked about subject today among computer personnel of companies with considerable experience in information processing is "management information systems." When companies first installed computers, they tended to isolate a given activity, such as payroll or accounts receivable, and develop a computer program for it. Usually, they simply computerized their previous manual procedures or punched-card system, viewing the firm as separable pieces such as sales and manufacturing rather than as an interlocking entity. Next, "integrated data processing" was in vogue; this was based on integrating the various applications into a single data processing system. Often the old organizational structure of the firm was found to be inappropriate to this approach. Such systems were usually an improvement, but they were still tied to the old concept of supplying historical data for accounting purposes. The information which management really wanted was still not available, and the system gave them little aid in making decisions.

Today the idea is to construct management information systems to provide information for operational decisions rather than for accounting purposes. Such systems are planned around internal computer utilities (although this is not crucial) with fairly elaborate terminals. A manager may sit at a terminal, request information, and have the computer manipulate it for him. Corporate plans can be filed in the computer and compared with actual performance. Simulation models of the firm and its environment will assess alternate strategies; computer programs will be available to optimize manufacturing scheduling, distribution of goods, plant location, etc. With an "online" system using up-to-date data, plans can be revised frequently.

Such utilization of computers permits better use of resources in the form of both labor and capital. In many instances, the increased productivity of capital resources which results may be as important as increased productivity of labor.

When organizations first install a computer, management science often rides piggyback on the computer, sometimes with results far exceeding those of mere computerization. In the early 1950's a water heater manufacturer who was turning out four sizes of heaters in three quality grades bought a small punched-card accounting system. Production was tripled and cost per unit reduced appreciably. But the truth was that the work the machines did could have been done by one or two clerks. Production was affected not by the punched-card system but through the management science introduced by the punched-card salesman for production scheduling and inventory control. Such experiences are not unusual.

This does not imply that the computer is unnecessary for most applications of management science and operations research. In fact, many are impossible without the computer. The point is that the computer often spurs the organization to take the so-called "total systems approach," examining the interplay between all the activities of the company. It forces the organization to ask "Why do we do it that way?" and "What are our goals?" The computer makes the company be systematic, often for the first time. The computer often forces an organization to examine itself to an extent it never did before.

Computer Manufacturers Will Assume More of the Burden of Providing Packages of Pretested Programs for Specific Applications and Industries

The cost of developing a specific program can be quite high. Further, instruction preparation must be preceded by analysis of the procedure to be mechanized and design of a process to carry it out. In the past, the cost of performing these functions has constituted a barrier to computer use, particularly by small firms. However to sell equipment to small organizations, computer manufacturers now offer, in addition to machines, packaged pretested programs for specific functional needs (e.g., sorting or inventory control) and to meet the special requirements of a given industry (e.g., hospitals). Similarly, computer service bureaus often develop and sell programs for specific applications.

Packaged programs represent a new force on the pace of technological change. In the past, only large firms could normally afford computer-applied management science and operations research. Their techniques were usually proprietary, and small firms had difficulty keeping up. In fragmented industries with many small producers, no one had the finances to be innovative. But now the computer manufacturer, service bureau, and computer utility are anxious to sell computer capability to small firms and are willing to invest in industry analysis, operations research, and packaged programs. For example, the apparel industry, although the fourth largest manufacturing employer, is made up of many medium-sized firms and has hardly been touched by computers up to the present.[5] Through the more aggressive selling activities of suppliers, computers and management science will be applied extensively to this industry in the next 5 years.

Utilization of Computers Will Become Economically Feasible for all Firms

As computers become less expensive, more firms will be able to afford one on their premises. Service bureaus are available today and economically feasible for many more firms than actually use them. Further, as computer utilities develop, inexpensive computing power will be available in small increments over communication links. Finally, computer manufacturers, service bureaus, or computer utilities will supply packaged computer programs to small firms at little or no cost (i.e., the cost will be buried in charges for computing power).

[5] Ellis, E. Meredith, "Estimates $30 Billion Will Be Apparel Industry's '65 Sales Figure," *America's Textile Reporter*, June 10, 1965, pp. 9, 11, and 49.

Computers Will Be Used to Control Complete Systems

Some years ago, the application of computers to the process industries (e.g., chemical, petroleum, power, and steel) was the subject of much, and as it turned out, rather optimistic speculation. Computers and the necessary instrumentation were too expensive and too unreliable, and the processes themselves were not well understood.

However, much progress has been made in recent years and as new instrumentation is developed, computer control of complete systems will expand considerably in many types of industries. Computers will be used to control manufacturing processes and, coupled with materials-handling equipment, to provide automatic warehousing. They will also be used for testing and quality control; e.g., to check out an automobile's electrical system before it leaves the assembly line.

Computers Will Be Used to Process Pictorial Images and Graphic Information

Computers were first used to manipulate numbers in scientific and engineering calculations and later to process alphabetic information for commercial applications. Now they are being used to manipulate pictorial information. In the simplest form of such processing the computer can only record, store, retrieve, and display pictures or drawings; it cannot manipulate the information in the picture or drawing. Nonetheless, such a system has many applications; e.g., a file of engineering drawings or correspondence files. In more advanced systems, the computer can manipulate the pictorial information and perform a wide range of sophisticated processes. For example, an architect can call forth a drawing and add or change lines, specifications, etc., by drawing on a special tablet or on the display. The computer can calculate such things as stresses and can evaluate the design from an engineering standpoint. The computer will not, however, be able to recognize complex patterns for a long time. That is, the computer will not be able to retrieve from storage the plans for the "house with the guest room over the garage," unless, of course, an index to such information had been prepared by humans in advance.

The computer's capability to process images and drawings together with its ability to calculate will revolutionize the designer's work in the next decade by making design less expensive and faster. Such systems are already being used to design such things as automobiles, airplanes, and computer circuits. In automotive design it is estimated that, by using these techniques coupled with numerically controlled machine tools, the present leadtime from initial styling to showroom floor of 28–30 months can be cut to 10–12 months.[6] Such machine aid can, for some applications, even make the design process economical enough to handle custom designed one-of-a-kind items.

The man-machine team can often be very efficient; e.g., buildings are being designed and built today with as much as one-third less steel than would have been required under previous techniques.

Computers Will Be Used to Process Language

The difficult subject of language processing presents a dichotomy similar to the one discussed above under image processing. In its simpler form of processing, the language is stored in the computer which can, based on the use of an index to find the correct words, parrot it back. For example, in the system recently installed for the New York Stock Exchange, up-to-the-second information is "spoken" by the computer in response to a code number for a given stock which is dialed into the computer over a private telephone line.

In more sophisticated systems, the computer will, in a sense, know the meaning of the language it has stored and be able to respond to complex inquiries after analyzing the language of the inquiry to determine what was asked for. While the problem is very difficult and progress will be slow, nonetheless, in the next decade many systems will be able to be queried in English, albeit with limited vocabularies and stylized syntactical constructions.

Systems already exist which mechanically translate some 100,000 words of Russian each day. The quality is not high, but the cost and elapsed time are such that the customer finds it useful. Whether machines will be able to translate within the next decade as well as an expert human translator is doubtful.

Input/Output Devices Will Become More Varied, More Flexible, and Less Expensive

As costs of the electronic portions of computers decline substantially, input/output costs will dominate, particularly for computer utilities. Consequently, considerable emphasis will undoubtedly be given to research and development aimed at reducing the costs of existing I/O devices and to inventing new ones.

Some of the existing devices are telephone sets, punched cards and tickets, paper and magnetic tape, keyboards of various kinds, character readers, printers, display devices, microphones and loudspeakers, tablets to write or draw on, measuring instruments which read directly into the computer, and actuators.

Terminals for Computer Utilities. The least expensive and most readily available terminal device for computer utilities is the telephone. If the voice recognition problem could be solved, it would be possible to speak instructions into a computer and have it respond in kind. But it appears that such a very difficult process will become feasible on only a very limited basis during the next decade. However, the dial and, more importantly, the touch-tone system with buttons which is just now becoming available can be used to introduce information into the computer system.

However, the telephone is quite inadequate for many applications. Its 10 positions restrict input to numerical information, or information must be coded as a number. No written record of the question or the answer is available. However, simple reading devices (e.g., an embossed plastic card) exist which can be attached to phones, and the development of inexpensive, simple printers that can be attached is a reasonable expectation. In time, the most common terminal device of an information utility will probably be a typewriter or something similar, although the typewriter has the drawback of a rather limited rate of input or output.

In addition to the typewriter, a display such as might be obtained from a television picture tube would be desirable. A display device, which might be in color and have greater resolution than today's television set, would permit a computer to present such pictorial information as a portion of a page from a Sears' catalog or the floor plan for an architect. In effect, one could "browse" through a catalog or file of information.

The more affluent user might want a device for reproducing on paper what was displayed (probably not in color for some years); a reader for the input of pictorial information, including printed material; a magnetic tape unit for recording various kinds of information, including video; a tablet to write and draw pictures on; and voice input and output.

With the exception of voice recognition, each of the above is technologically feasible today. Though quite expensive, much of it is economically feasible for such specialized applications as automated design. By 1975, this "Cadillac" of terminals may cost no more than a Cadillac. But even if the cost were much greater, many firms would find such a system economical, and large firms would have many. Even many individuals will be in a position to afford such a system, with the cost justified by an increase in the user's productivity.

Character Recognition. The use of character recognition devices for putting information into com-

[6] "Finding New Ways to Make Autos," *Business Week*, Sept. 11, 1965, pp. 190–198.

puters will expand considerably. Such systems have been in use for a number of years in banking, credit card applications, utility billing, etc., but they have been limited in the sense that they distinguish among only a few different symbols (14 in the banking system) printed in a highly stylized font. However, systems are now available for handling character sets with many symbols and in a variety of type faces, and though still quite expensive, they are economically feasible for large-volume jobs. Since they contain much electronics, they can be expected to become less costly.

In the future, in those instances where the data must be typed in order to be fed into a character reader, it will normally be less expensive to bypass the character reader by having the typewriter connected directly to a computer utility. This will permit editing the data and putting it into a format.

Character recognition systems will be used increasingly for reading printed documents such as airplane tickets and "turn around" documents. An example of the latter is a magazine subscription renewal notice mailed to a customer with information printed on it by the computer. The subscriber puts a check with it, and "turns it around" by mail to be read by the machine.

If reading typewritten characters is difficult, reading handwritten characters would seem impossible for computers. However, the problem can be simplified and solved; e.g., we can train the writer to make characters in a special way. Thus we have the equivalent of the highly stylized font used on bank checks. If the machine can capture the information as it is written (which it could if a man were writing on a tablet at a terminal of a computer utility), the problem is easier. Further, if the machine can immediately display back to the writer the output of its recognition process, the writer can check its correctness and try again if necessary. Such systems exist in the laboratory today.

However, there is little likelihood in the next decade that a machine will be able to recognize an undisciplined scrawl. Signature verification and identification of individuals by their handwriting are simpler problems and will be done by computers before the general problem is solved.

Voice Recognition. A subfield of pattern recognition with important implications for the future is voice recognition. To the author's knowledge, no voice recognition system is presently in use on a daily basis. Laboratory work has been going on for some time, and fairly reliable systems exist where a few speakers can use a few simple sounds, such as the 10 numeric digits. A voice recognition device capable of recognizing numbers, letters, and a few one-syllable words would have a large market, and may exist at a reasonable price by 1970. Systems capable of handling larger vocabularies (500–1,000 words) will probably exist by 1975. Even the simpler of such systems would be useful for direct inquiries into an information utility via telephone or radio.

The problem of identifying who spoke is apparently somewhat easier than understanding what is said, particularly if the system is asked only to verify that the speaker is who he claims to be (assuming his voiceprint already exists in the machine). Should a market develop, such identification systems could probably be available within 5 years.

Fingerprint Recognition. Systems capable of identifying individuals whose thumbprints are on file may be available within 5 years. Some experts believe that such systems may be realized within 18 months.[7] In addition to their obvious applications in law enforcement, these devices may become inexpensive enough for business to make the thumb the universal credit card (which cannot be lost or stolen).

Pattern Recognition. Many other pattern recognition tasks could have considerable impact if done by computers. For example, the ability to recognize meaningful patterns in electrocardiogram and electroencephalogram traces and in photomicrographs of biological cells would improve and reduce the cost of medical care.

The Extent That Information Utilities are Used Will Depend on Communication Costs and Capabilities

The information utility concept and the expanding use of computers discussed here are dependent on efficient and low cost communication. Demand for data communication capability will increase tremendously in the next decade. As might be expected, communications and computer experts disagree on whether communications or computer technology will limit the introduction of information utilities which are dependent on both. Communications experts point to large projected investments in new facilities, and they anticipate that data transmission volume will exceed voice transmission prior to 1970. On the other hand, computer experts believe the demand may be even greater than that anticipated by the communications specialists; they also fear that a communications plant designed for an earlier era may not be able to handle appropriately the type of communications required in the era of the information utility. For example, at present, the minimum period of time that can be bought is 3 minutes; yet a computer utility user might need but a few

[7] Tom Goff, "Criminal World Faces Duel With Computers," *Los Angeles Times*, July 11, 1965.

thousandths of a second at a time. One reason for the large minimum is the slowness of present electromagnetic switches used in telephone central offices.

Beginning in a few years, the telephone industry plans to install electronic switching systems at the rate of about one new electronic office each day; but even at that rate, the replacement will not be complete until around the year 2000. Of course, the change will first be made in the large metropolitan centers where the demand for data transmission will be greatest. Nonetheless, at the projected installation rate, the changeover will not reach 50 percent completion until after 1980.

Some computer experts believe that because this replacement system has been designed primarily to handle the traditional voice (analog) traffic, it will not provide the best system for handling data (digital) traffic. Therefore, they suggest consideration of other possibilities for handling the digital load; e.g., a new all-digital communication system specifically designed for digital traffic that could easily handle voice traffic as well, and could offer other advantages. While they agree that such an implementation would be costly, they point out that so is the common carrier plant.

It appears to be of utmost importance from the standpoint of the information utilities to create a national communications system which—

(a) is designed for very rapid growth in digital traffic;
(b) is capable of changes in function to keep pace with technology;
(c) provides *secure* user-to-user and computer-to-computer communications;
(d) provides dynamic control of priority; and
(e) allows the user to purchase quite small increments of time with electronic switching speeds.

The question of whether the computer or the communications experts are right (a question of economics as well as technology) is far beyond the scope of this report. However, since the communications industry is Government regulated, what happens in this field is very much a function of Government policy and not solely the result of the forces of the marketplace. The subject deserves considerable study to insure that Government policy is conducive to the growth of communications facilities appropriate for the era of information utilities.

The Computer Has Accelerated the Pace of Technological Change in the Past and Will Continue To Do So

Although scientific and engineering applications of computers have thus far been virtually ignored in this report, such use still accounts for a large percentage of the total computing power consumed. The growth of technology in some fields, such as nuclear physics and space, has been completely dependent on computers. Other fields have been essentially untouched—but they will not be for long.

In the past, even in fields of science and engineering where computers have been used, their application has been limited by the relative difficulty of operation. It has been estimated that fewer than 20 percent of the engineers and scientists who should use computers ever do so. However, coupling better higher level languages with an online terminal of a computer utility will have a strong impact on computer use by engineers and scientists, and therefore will increase the pace of technology. Further, the use of graphical information processing will increase the efficiency of designers.

The computer not only permits the scientist to collect and analyze more data, but it is assuming an integral role in the experimental process. In particular, the computer is now used to control laboratory experiments directly, increasing speed and permitting more complex experiments.

In time, the advent of the information utility will make it feasible to develop information retrieval systems for given areas of knowledge which can be interrogated by anyone. Progress will be accelerated when what is already known becomes more accessible. However, really effective systems which approach the capability of an expert who really knows the literature of his field present formidable problems that are not likely to be solved for some time.

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IV. Applications of Computers

In this section, detailed attention will be given to the use of information processing in two areas—banking, credit, and financial information, and government—where computer utilization has the potential for effecting large changes. Less detailed discussion will also be devoted to several other areas of computer application.

Banking, Credit, and Financial Information

The Present. Next to the Government, the commercial banking system is the largest processor of paper. In 1964, for example, the system handled 15 billion checks in addition to its other financial transactions. In the last 6 years, check handling has been largely automated, with over 90 percent of the checks in circulation today MICR-coded. (MICR stands for Magnetic Ink Character Recognition and is the scheme adopted by the banking industry for printing information on checks that can be read by character recognition machines.)

Almost all large banks have their own computers for check handling and many other applications. Many smaller banks have mechanized or are planning to do so through the utilization of computing services offered by a correspondent bank, computer service bureau, computer cooperative formed with other banks, or by the installation of sophisticated electronic bookkeeping machines. However, as an indication of the conservatism of some bankers, 45 percent of the banks (mostly small ones) replied to a 1962 questionnaire of the American Bankers Association that they had no intention of using a computer in the foreseeable future.[8]

Despite the introduction of computers, bank employment has continued to grow, thanks to the rapid growth of the industry as a whole. However, the rate of growth of employment has slowed down; and despite the overall growth, the bookkeeping function has been greatly affected by the introduction of computers. Some banks have reported reductions in their bookkeeping staffs of as much as 80 percent. For multibranch banks, the bookkeeping function has almost disappeared at the branch level. Despite this, however, the number of women employees as a percentage of total employment in banking dropped less than 1 percent from 1960 to 1964.[9] While bookkeepers have been disappearing, a new category of employee, associated with computer operation, has appeared.

Clearly, productivity has increased considerably in banking and will continue to do so. However, we lack a good measure of productivity and cannot say by how much it will increase.

In the short term, computer utilization will spread to most unautomated banks, and the number of applications in banks already using computers will increase. Total employment will continue to increase, although this will be of little solace to the displaced bookkeeper. New applications will result in increased productivity but will have little impact on employment.

Equipment trends will include increasing use of optical character-recognition equipment for documents other than checks and the introduction of teller terminals attached to a computer utility. For the larger banks, the computer utility will be inhouse, while the smaller banks will be served by an organization which serves a number of firms. Terminals will improve teller productivity, but the impact on employment will be masked by the growth of the industry.

Banks, particularly the large ones, will expand their services to include payroll, professional billing, account reconciliation, accounts receivable, inventory control, stock and bond portfolio analysis, bill collection, asset management, analyses of retail market penetration, economic forecasting, etc.—all essentially dependent on the use of a computer. Banks, thus, are already moving into the computer utility area, although for most existing applications the communications link remains the U.S. mail service or a courier. In California, however, the Bank of America offers a service to physicians and dentists whereby all charges and payments are reported each day over the telephone (augmented by a simple keyboard device) to the bank. The bank prepares monthly statements on its computer, mails them to the patients, and sends accounting reports to the physician or dentist. Typically, this system reduces accounting and billing time in the medical office by about 80 percent.

These new services not only affect the banking industry; they change the ways of handling busi-

[8] *Automation and the Small Bank,* American Bankers Association, 1964.

[9] *Employment and Earnings Statistics for the United States, 1909–64,* December 1964, Bull. No. 1312–2, U.S. Department of Labor, Bureau of Labor Statistics, 1964.

ness data and financial transactions in many other industries.

The Future

> Automation affects not the mere mechanics of banking, but the very foundations of banking; not the individual bank, but banking systems and the national and international economies in which they are imbedded.
>
> —Anthony G. Oettinger[10]

The computer has forced the banking industry to examine itself to an unprecedented extent. Technological advances in computers and communications underscore the fact that banking is a system of national scope—in fact, worldwide scope.

The banking industry has observed that much of its activity could be eliminated, and there is a movement afoot to reduce drastically the paperwork in financial transactions—ultimately to do away with the check altogether. Other than cash, the simplest system would involve telling a financial computer utility via a store's terminal to transfer the amount of the sale from the buyer's to the store's account. If the purchaser's balance wouldn't cover the cost, the financial utility could extend him credit if his credit rating was good.

Many other less esoteric possibilities are already in use. For regular payments of a fixed amount, like mortgage and insurance premiums or utility bills up to a given amount, the bill can be sent directly to the person's bank for payment. Other schemes involve using slightly augmented home telephones to instruct a bank to transfer funds to another account. (Such a system was demonstrated at the 1965 meeting of the American Bankers Association.)

If businesses of all sizes have simple terminals linked to a central computer utility over a communications network, a universal credit-card system is possible. Various schemes could be used to make it difficult for someone else to use your "card"; e.g., a "combination" key number known only to you; or ultimately, recognition by voice or thumbprint. Except for recognition by voice or print, all of the above is technologically feasible today. Pilot systems have been built and demonstrated, and economic feasibility is close at hand. But State and Federal laws will have to be changed and banks might have to agree to fundamental changes in systems and organization. For example, banks, savings and loan associations, and loan companies in a geographical area might establish a jointly owned and operated financial computer utility to serve the community.

Such a financial utility could develop a complete credit-deposit-loan history for each customer. This history could also enable the financial utility to be a more effective financial adviser to the customer, pointing out spending habits, making analyses, and helping with better financial planning. Tax returns could also be turned out semiautomatically.

A financial utility could provide many other services; e.g., inventory control for sellers. Up-to-the-minute statistical information on other community activities could be made available.

In the system described above, money could be transferred from account to account or the transaction could involve the extension of credit. The credit could be given by the seller, based on an indication from the financial utility that the buyer was a good credit risk, or the credit could be extended by the utility. The latter scheme would probably mean less expensive credit for the buyer, since much of the cost of credit today goes toward the administrative costs of recordkeeping. Centralized in the financial computer utility, the costs of such recordkeeping would be lower.

No matter how credit is extended in the future, the credit information industry will undergo major changes in the next few years. Once again, existence of the computer is causing a close examination of present practices; e.g., the tremendous redundancy in information files on people and companies maintained in hundreds of places in a community, each with file clerks and credit managers. Not surprisingly, computerized credit bureaus are being established around the country: One is already in existence in Los Angeles and will soon cover all of California, and systems are also underway in New York and Texas. Needless to say, this portends the end of many small credit bureaus as well as the elimination of many jobs concerned with credit in companies which elect to buy this service. In California, for example, the large banks have signed up with the new credit information utility.

It is difficult to know how soon the financial information utility will come into being because the determining factors are social and political rather than economical or technological. Martin Greenberger suggests that it may be 25 to 30 years.[11] Rudolph Peterson, president of the Bank of America, predicts that we shall see a drop in the use of checks by the public in about 5 years. Dale L. Reistad, director of automation and marketing research for the American Banking Association, believes that citywide universal credit-card systems will soon come into existence and will be followed by areawide systems, finally forming a nationwide credit system by 1975.[12] The forces of the marketplace will operate to bring such systems into existence—where there are large savings, there are large markets and profits. (One company,

[10] *Proceedings, National Automation Conference*, American Bankers Association, New York, July 13–16, 1964, p. 38.

[11] Martin Greenberger, "Banking and the Information Utility," *Computers and Automation*, April 1965.

[12] Dale L. Reistad, "Banking Automation—1975," *Banking*, Journal of the American Bankers Association, July, October, and November 1964.

Sperry Rand, has already developed the hardware for such a system and has demonstrated a pilot setup.)[13]

Computers in Government

The Present. Of the total number of computers installed in the United States today, about 10 percent are used by the Federal Government. Of these, about 7 percent are in the Department of Defense, with NASA and the AEC accounting for another 2 percent. Thus, nondefense and nonspace related computer activities of the Federal Government comprise only about 1 percent of the total computers installed.[14] The percentage of computers used by State and local governments is about 2.5 percent, up by a factor of about 5 since 1960.[15]

A vast potential exists in the utilization of computers in government, for much of its activity involves information processing. A study for the State of California by Lockheed Missiles & Space Co. estimates that the State's 100,000 employees spend 50 percent of their time processing information.[16]

As in industry, the first phase of utilization by government has involved the mechanization of existing manual systems or of punched-card procedures. Even though this phase has hardly begun, the next—intergrated data processing—is underway and organizations have begun to examine their operations to an extent they never did before. This second phase is proceeding at such a pace that some organizations will undoubtedly bypass the first.

Government organizations have conventionally organized files according to use; e.g., police, welfare, accounting, education, employment data. As a result, there is extensive duplication in collection and storage. Information collected by one group is often unknown to others who could make good use of it. Because of jurisdictional, mechanical, or procedural problems, data are not shared efficiently among various groups. Often information which would be very useful to one organization is not collected at all, even when another group could easily gather it in the normal course of operation.

The information with which government is concerned deals with people, organizations, real property, and personal property. Much of this information is common to many agencies; i.e., a person or a piece of property falls within the purview of different agencies for different purposes. Thus, the integrated data processing approach suggests that data files be organized by person and property and shared by all agencies rather than each agency having a file of its own. Shared files would not only reduce costly duplication but provide more comprehensive information than would otherwise be possible.

Integration Across Functions. An example of a file organized around property, and thus across several functions, is the data bank of Alexandria, Va., which contains information about the city organized into two master files. The street section file contains 120 items of information about the 3,518 blocks and intersections in the city; the parcel file contains 91 types of information about 20,000 parcels of land. Recently, within 1 week, six governmental managers made requests for information. Typical of these were:

> Survey all intersections in the city showing those where 5 or more accidents occurred in the past 3 months and give the characteristics of each such intersection.
>
> For two proposed urban renewal areas, analyze the density and location of welfare cases, minimum housing-code violations, health hazards, fires, mortalities, crimes, and arrests.

All six requests were fulfilled from the data bank that same week at a total cost of 3 hours of staff time and $67.50 for computer rental.[17]

Integration Across Political Boundaries. Data processing can also be integrated over political boundaries. Because of urban sprawl and the high mobility of our population, information on the same individual may appear in the police files of a dozen or so cities, often in different States. Similarly, because of overlapping jurisdictions, health or welfare data on the same individual may exist in many places.

The Police Information Network (called PIN) of a nine-county area around San Francisco Bay integrates such information through a centralized electronic file of warrants of arrest. For example, a policeman who stops a motorist can radio the license plate number and name to headquarters where the information is typed into an inquiry terminal connected over a communications network to a computer. Within 2 minutes the policeman will know if any warrants are outstanding against the person in any of the 93 separate law-enforcement districts in the 9 counties and if the car is stolen or wanted in connection with another crime. The California Highway Patrol also operates a statewide stolen and wanted automobile system.

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[13] *Consumer Purchasing Service*, Sperry Utah Co., Division of Sperry Rand Corp., Salt Lake City, Utah, 1965.

[14] "The House of Representatives Passed the Amended Version of the Brooks Bill," *EDP Weekly*, Sept. 6, 1965, pp. 14–15.

[15] "EDP in State and Local Governments at Mid-Decade," *Automatic Data Processing Newsletter*, vol. IX, No. 25, May 10, 1965.

[16] *California Statewide Information System Study*, Final Report, Lockheed Missiles & Space Co., July 30, 1965.

[17] "Small Cities and Time-Sharing," *Public Automation*, vol. 1, No. 1, June 1965.

Duplication. Some 14 million name records were in the files of just 12 of the agencies involved in PIN, although the total population of the 9 counties is about 4 million. Alameda County, also in the bay area, discovered in the process of developing an information system integrated across several functions that the county had 57 different files on people.

Duplication also exists between State and Federal organizations, their field offices, and local government counterparts. To indicate the possibilities for overlap, the United States has 50 States, 3,043 counties, 17,144 towns and townships, 17,997 municipalities, 34,678 school districts, and 18,323 special districts.[18] The number of separate agencies among these 91,236 areas apparently has never been recorded.

Benefits to be Derived from the Use of Computers in Government. 1. Cost savings should result from the elimination of duplication, from increased productivity in information processing, and from better utilization of resources through planning. More comprehensive, current, accessible, and accurate information should result in better decisionmaking.

2. Collection of more revenues should result through better audit, followup, and uniform application of complex rules.

3. Services to the public should be improved and expanded. This benefit is most important, although difficult to measure.

Examples of These Benefits

1. *Cost Savings*

The Lockheed study [19] estimates that increased productivity would reduce personnel costs by between 1 and 5 percent—more than sufficient to pay for the system; in fact, at the upper end of the estimate, savings per year are 10 times annual costs. This estimate would seem conservative, since it does not consider savings due to elimination of duplication.

St. Louis County saved $3 million in construction costs of a junior college by using a computer program which schedules classroom use. Classroom utilization was increased from the usual 30 to 40 percent to 80 percent, and fewer classrooms were needed.[20]

The cost effectiveness methods, so dependent on computers, that were introduced into the Department of Defense by Secretary Robert McNamara and his comptroller, Assistant Secretary of Defense Charles Hitch, could be used throughout the Federal Government and at State and local levels as well for evaluating various approaches to a problem.[21]

2. *More Revenue*

The Internal Revenue Service reports that in 1964 people reported $2 billion more in interest income than on 1963 individual income tax returns—a 28-percent increase. The IRS credits the use of computers and the public's awareness of what they can do for most of the increase, even though its computers processed individual returns in only one of seven regions last year. Collections from tax-delinquent businesses also increased when computers were installed.[22]

The use of computers can also increase the collection of fines from traffic warrants (it has been estimated that the PIN system will generate $2 million a year in fines that would otherwise go uncollected), and can help track down estranged fathers of children on welfare rolls; etc.

3. *Improved and Expanded Services*

A certain amount of unemployment is due to the time it takes for the unemployed to obtain information about appropriate job openings and for an employer to obtain information on qualified applicants. An information system designed to match the unemployed with job openings should hasten the reemployment process, and not only reduce the human misery of unemployment but also clerical costs and the costs of unemployment insurance.

The PIN system discussed previously is a very limited example of the application of EDP techniques to law enforcement. A much more ambitious system is under development for New York State, involving a statewide centralized information utility integrating the complete files of over 3,600 law enforcement agencies, including police, prosecutors, criminal courts, and probation, parole, and correction offices. The first phase is scheduled to begin in 1967 with the complete system to be operational by 1969.[23]

Not only should better information lead to better law enforcement, but hopefully with much more information about crime, we might gain some insights into the causes and the cures for crime and delinquency and thus map out a broad strategy of crime prevention.

Another new application of computers is in the legislative process. With pending legislation and

[18] Philip Meyer, "Too Many Governments Spoil Your Griping?" *Standard Star*, New Rochelle, N.Y., June 4, 1965.
[19] *California Statewide Information System Study, op. cit.*
[20] "School Scheduling," *Public Automation*, vol. 1, No. 2, July 1965, p. 3.
[21] "The Computer and the Pork Barrel," *Saturday Review*, Aug. 28, 1965, pp. 14–15.
[22] "C&A Capital Report," *Computers and Automation*, July 1965, p. 35.
[23] Ezra W. Geddes, Robert L. Ewich, and James F. McMurre, *Feasibility Report and Recommendations for a New York State Identification and Intelligence System*, System Development Corp., Nov. 1, 1963.

proposed amendments and their status kept in a computer, each day the legislators could be brought up to date on where things stood at the close of the previous session. Such a scheme has been used in Ohio for appropriation bills. When better methods for processing language are available, proposed legislation could be compared with existing statutes for conflicts. However, for some time the best that such systems can do is to retrieve pertinent sections from present laws for comparisons by humans.

Another long-term and somewhat tenuous benefit to the individual citizen is that computers will tend to expose unsystematic administrative procedures, thus encouraging administration to become more uniform and less susceptible to political "pull." However, being systematic and objective can lead to inflexibility.

Pertinent Technological Developments. Information and information processing will become less expensive and more readily available to government as well as to industry. Computerized management information systems will also become important tools, and the development of large-scale mathematical models for simulating the economy of a region or of the entire Nation should contribute significantly to economic health in the 1970's.

Of great importance to law enforcement would be the development of the fingerprint-recognition device previously discussed.

Effect on Employment in Government. The application of computers will have a significant impact on productivity in government because government activities involve a great deal of information processing, and because there exists so much duplication in collecting, storing, and retrieving data. But it is doubtful that there will be wholesale displacements of personnel; certainly the experience of the Federal Government to date would indicate otherwise. In a report to Congress in 1964,[24] the U.S. Civil Service Commission reported that in 10 agencies reviewed, only about a tenth of 1 percent of their personnel had been separated, reassigned, or declined reassignment because of the introduction of computers and automation. These agencies, when asked to forecast their future personnel requirements, anticipated a decline of 5,000 in clerical positions but increases of over 10,000 in other jobs—chiefly those related to computer operation. These numbers are all of the order of a fraction of 1 percent of the Federal work force.

This should not be taken as an indication of insignificant productivity increases. Services have been increased, Parkinson's law has been at work, and "silent firings" (a reduction in the need to hire new employees) are the rule. The 1965 *Manpower Report of the President* anticipates that the number of Federal employees per 1,000 population will decline by about 2 percent between 1964 and 1968. It further states that electronic data processing has been a major factor in reduced growth in Federal employment, and has led to substantial changes in the composition of work forces.

As an example of an extreme increase in productivity, the report cites the Division of Disbursement of the Department of the Treasury where output per man-year increased by more than 300 percent while the dollar-cost per 1,000 checks and bonds was more than halved between 1949 and 1962.[25]

Though totals remain stable, they can mask significant changes. For example, the Internal Revenue Service's computerization plan calls for the centralization in 7 regional offices of processing tasks previously performed in 62 district offices. Although a greater number of new jobs will be created in the regional centers, some 5,000 routine office jobs in the district offices will be eliminated. Similarly, the optical character-recognition device to be installed at Social Security Administration headquarters will replace 140 keypunch machines and their operators.

The Computer as a Force Toward Consolidation. The Government use of computers will add to the already great pressures for consolidation of local government. Computers may strengthen the position of counties with respect to cities, of States with respect to counties, and of the Federal Government with respect to States. The most common form of consolidation to be expected in the near future is exemplified by the PIN system where only *files* are consolidated and shared, but not authority.

Factors Influencing the Rate of Introduction. Technological feasibility is hardly a problem. Economic feasibility is certainly at hand for many governmental activities not now computerized; and as computers become less expensive, many more applications will become practicable. Within a few years, computerization of almost all large governmental information processing tasks will be economically feasible, with better service at reduced costs the justification. However, the rate of introduction will be held back because of the following:

1. The unfamiliarity of top-echelon personnel, in general, with the principles of electronic data processing and with recent advances in manage-

[24] *A Study of the Impact of Automation on Federal Employees*, prepared by the U.S. Civil Service Commission and referred to the Subcommittee on Census and Government Statistics of the Committee on Post Office and Civil Service, House of Representatives, 88th Cong., 2d sess., August 1964.

[25] *Manpower Report of the President and A Report on Manpower Requirements, Resources, Utilization, and Training*, U.S. Department of Labor, March 1965.

ment science will remain a substantial deterrent, although attempts are being made to rectify this situation.

2. There is a serious shortage of qualified personnel required to do staff studies and analysis. Government has difficulty in competing with industry for well-qualified computer professionals, who are in great demand and command high salaries. This, plus the situation discussed in (1) above, will contribute to a number of failures in applying information technology to government processes.

3. Authority is diffused as to what information is to be obtained, who is to have it, and how it is to be kept. Laws will often have to be changed to permit integration of files.

4. There is a lack of cohesiveness and coordination among organizations. For example, some State agencies, particularly those dealing in welfare, health, and roads, are more oriented to Washington than to their own State administration.

5. Parochialism inhibits integration across various levels of government, especially where organizational changes are necessary. In the face of such parochialism, the Lockheed report [26] proposed a federation of semiautonomous computer centers linked by an information central with information about where specific data are located. However, when problems become severe, political subdivisions will accept centralization: e.g., metropolitan water districts, transit districts, and police information networks.

6. The introduction of integrated files on individuals will be slowed by the not unfounded fear of a "1984 Big Brother" life with its invasion of individual privacy. This will be discussed later.

Despite these deterrents, computer use by State and local government increased about fivefold during the past 5 years. Computing power undoubtedly grew much faster—in the country as a whole it increased by a factor of about 30. In the coming decade, computer utilization in government will grow faster than in the rest of the economy. Most applications in the near future will be the computerization of existing manual procedures or of punched-card systems. Some integrated systems will appear, especially in law enforcement and particularly after the completion of pioneering applications like the New York State Identification and Intelligence System (scheduled for 1969). Once the decision is made to go ahead, it will take from 7 to 10 years to build the California Statewide Information System, which will involve almost complete integration across all functions and all geographical boundaries. (The decision to centralize geographically only information about data rather than the files themselves lessens the difficulties.) In contrast, the less ambitious New York system, while covering all the State, does not represent nearly as much functional integration.

[26] *California Statewide Information System Study, op. cit.*

The Publishing Industry

The impact of computers on publishing was very much in the news in 1965. The newspaper industry, in particular, became entangled in many labor-management problems directly as a result of automated composition proposals.

Automation in this industry dates back to the 1930's and involved typesetting equipment operated by teletype tape. Next the computer was added to produce the tape from material typed into the system, with the computer determining what should be on a given line, justifying and hyphenating as appropriate. Another step did away with hot metal through phototypesetting. The computer is also used in page makeup.

The latest developments are feasible both technologically and economically, and the rate of introduction will depend on labor agreements. The imminent obsolescence of the linotype operator is analogous with that of the railroad fireman.

Computers will be used in other areas of publishing: Material which is typed, edited, reworked, typed again, edited, reworked, and typed again will be typed into a computer from which it can be retrieved, edited, and reworked with a minimum of recopying. Simple systems of this kind, using a typewriter as a terminal, are in use today. Experimental systems using a television picture tube to display text also exist. Such systems not only reduce the amount of proofreading and typing but speed up the overall process. Once the material is in final form, the computer can feed it into a phototypesetter and produce a tape for later use or print the material for subsequent duplication. When image processing is added to the system, it will be possible to manipulate text and images simultaneously.

Information utilities may affect the publishing industry in another way: Some material that is printed today may be produced in smaller volume or possibly not printed at all. For example, books containing reference material that changes significantly in a short time might not be printed if the information utility can supply the information.

Agriculture

Computer use in agriculture is in its infancy (less than 1 percent of U.S. farmers use such systems), but will probably become widespread in the next decade. Even small farmers, dealing with a computer service bureau by mail and eventually with a computer utility by telephone, can use computers profitably for recordkeeping, accounting and planning.

The computer will enable the farmer to:

- Reduce clerical costs;
- Know which operations are showing a profit;
- Know which animals are paying their way;
- Do a better job of financial management and reduce what he pays for credit;
- Better manage labor, machinery, and other resources;
- Determine "least-cost" rations for his animals;
- Compare his performance with the average and best performance of other producers in his region.

Such EDP services are available from the agricultural extension services of a number of State universities and from several commercial organizations, including banks, with users reporting overall cost savings of from 5 to 20 percent with the more sophisticated systems. Thus computers will soon be contributing significantly to productivity in agriculture.

Insurance

The insurance industry, which deals primarily in information, naturally became an early user of electronic data-processing equipment. First applications were mechanizations of previous manual and punched-card processes. Integrated systems soon followed, often requiring a change in the organization of the company.

As a result of having entered the field early, the insurance industry has been almost completely penetrated by computers, and their major impact is now past. Most affected were the clerical workers. Yet, despite considerable increases in the productivity of the clerical force, the percentage of women employees in the total work force among insurance carriers fell only about 1 percent from 1958 to 1964.[27] Some continued increase in productivity in clerical operations can be expected. For example, the increased use of optical character recognition equipment will displace some keypunch operators and clerks.

Two developments in information processing will be important to the insurance industry in the future. The first is the introduction of the computer utility concept permitting terminals in the field throughout the country to be connected via a communications network to computer files in the home office. This will permit agents to give better and quicker service to their clients as well as reducing clerical costs. The second is the application of computers to underwriting, which is already being done by some companies, although only on policies of low face value and low risk. It is anticipated that this application will grow and reduce somewhat the need for underwriters.[28]

[27] *Employment and Earnings Statistics for the United States, 1909–64, op. cit.*

[28] Robert C. Goshay, *Information Technology in the Insurance Industry*, Richard D. Irwin, Inc., Homewood, Ill., 1964.

Computers and Health

The application of computers and information processing technology to health problems promises significant advances during the next decade in several ways:

1. The computer will take over much of the clerical work and information handling of those engaged in medical care;
2. Computer technology will provide more comprehensive information about each individual's medical history, resulting in better medical care;
3. Computer technology and automation will be applied to medical testing, resulting in cost reductions which, among other effects, will permit significant reductions in the costs of preventive medicine;
4. Computers will aid the physician is diagnosis;
5. Computers will be used to monitor the vital signs (e.g., blood pressure) of the seriously ill;
6. Computers as a research tool will aid in advancing medical knowledge;
7. Computers in the form of an information utility will aid in the dissemination of up-to-date knowledge to physicians.

Let us look at each of these applications in more detail:

1. As was often the case in industry, the first applications of computers in medical care involved the mechanization of manual procedures or punched card systems for such things as hospital payrolls and patient billing. Penetration of this phase of computer utilization into hospitals is far from complete, being limited to the larger and more progressive hospitals. Despite this limited penetration, there is already much interest in hospital information systems designed not only for accounting tasks but also to provide better medical care at a reduced price (with accounting information as a byproduct). Studies show that many hospital nurses spend as much as 40 percent of their time doing clerical work, and that test results and prescription orders may be transcribed as many as 10 times.

The hospital information system concept normally involves terminals at each nursing station and at such localities as admitting, pharmacy, medical records. laboratories, etc., connected to a central computer, which may be in the hospital or many miles away. Such a system would not only reduce the clerical load of administrative personnel, but also of doctors and nurses. Hospital care is one area where increased demand for services will rapidly absorb any increases in productivity. As a nation, we have been devoting more and more of our growing gross national product to medical care, while the number of professionally trained personnel per thousand population has been declining. Increased productivity is badly needed. Hospital employment has shown an average growth of 5.4 percent per year since 1958,[29] and will soon feel the added stimulus of the Medicare program.

2. One of the more important ways in which information systems will improve medical care will be through computer-based medical record systems containing the complete medical history of each individual in a geographical region. Such an information utility could be interrogated by a doctor or a hospital, even when the patient is far from home. Problems such as standards on terminology and data collection, deciding what is important to record and transmit, etc., will have to be solved before such systems can be made workable. But because of their obvious social value, we can anticipate that a large effort will be devoted to solving these problems and developing less ambitious systems. Large amounts of medical data in computer-processable form will also be of great value to medical researchers.

3. Much effort is presently being devoted to automating various medical tests in the interest of improving medical care and reducing costs. Hopefully, the costs of a number of important tests can be reduced to the point where they can be routinely given to everyone in a program of preventive medicine. For example, even if we could presently afford to administer electrocardiograms to everyone annually, there are not enough doctors to analyze them. Ample evidence indicates that computers could at least select those electrocardiograms requiring further examination by a cardiologist and could probably do an adequate job of classifying abnormal cases.[30] Cost reductions of a factor of 10 appear quite feasible for many tests.

Two North Carolina hospitals recently automated a laboratory where 11 chemical tests are routinely run on the blood of patients, as contrasted with the usual 2 standard determinations. Unexpected data of direct benefit to the patient were found in 1 out of every 15 admissions.[31]

Another example of the use of computers in a program of preventive medicine exists at the Kaiser Foundation Health Plan in the San Francisco Bay area. On entering the clinic the patient is given a self-administered questionnaire of some 600 questions about his medical status. His answers and the results of a number of tests (blood tests, electrocardiogram, etc.) are fed into a computer, which makes a "provisional diagnosis" that is used by physicians in subsequent examinations.

4. Although computer-aided diagnosis is primarily confined to research efforts at present, the results give promise of providing a useful operational tool for the physician in the next decade.[32] The computer will not replace the judgment of the physician, but rather will be a valuable aid to him in arriving at a diagnosis, much like a consultant who suggests one or more tentative diagnoses. The computer process could also suggest tests which would enable the physician to decide among several tentative diagnoses or to confirm the one tentatively arrived at. In most instances the physician would undoubtedly have called for the same tests, but in these days of advanced medical science, there are many diseases and medical conditions which a doctor seldom encounters.

More important, in a program of preventive medicine, the computer in the 1970's should be able to digest facts about the present medical status of individual patients (the majority of whom are healthy) and separate out those cases warranting the further attention of a doctor. The computer process would intentionally be conservative; if there were any doubt, consultation with a physician would be indicated. While it is true that most patients might not be seen by a doctor under such a system, at the present time most apparently healthy people in the United States do not receive periodic medical checkups at all. Thus, we have here another situation in which society can readily absorb the increased productivity brought about by computers, automation, and technological progress.

5. Computers capable of monitoring such physiological variables as pulse, blood pressure, and temperature have been much discussed in recent years, and experiments have been carried out in intensive care units.[33] One expert has estimated that as many as 10 heart deaths out of every 100 could be prevented if patients were in an intensive coronary care unit where electrocardiograms and pulse rate were continuously monitored.[34]

The use of computers to monitor these variables will undoubtedly gain wide acceptance in intensive care units, but will probably not be applied generally in hospitals during the next decade because of high costs and the fact that the measuring instruments tend to be uncomfortable and bothersome.

6. Computers are used extensively today in medical research centers, and their use as research tools will undoubtedly grow rapidly. They are used to collect and analyze experimental data, sometimes with the computer controlling the experiment based on immediate analysis of the in-

[29] *Employment and Earnings Statistics for the United States, 1909–64*, *op. cit.*

[30] H. R. Warner, A. F. Toronto, and L. G. Veasy, "A Mathematical Approach to Medical Diagnosis. Application to Congenital Heart Disease," *J.A.M.A.*, vol. 177, 1961, pp. 177–183; and H. R. Warner, A. F. Toronto, and L. G. Veasy, "Experience with Bayes' Theorem for Computer Diagnosis of Congenital Heart Disease," *Ann. N.Y. Acad. Sci.*, vol. 115, 1964, pp. 558–567.

[31] John A. Osmundsen, "Automation Used for Blood Tests," *New York Times*, Sept. 12, 1965.

[32] John A. Jacquez (ed.), *Proceedings of a Conference held at the University of Michigan, May 9–11, 1963*, Ann Arbor, Mich., 1964.

[33] Robert L. Patrick and Marshall A. Rockwell, Jr., "Patients On-Line," *Datamation*, vol. 11, No. 9, September 1965, pp. 57–60.

[34] John A. Osmundsen, "Electronic Units Aid Heart Patient," *New York Times*, Oct. 16, 1965.

formation being collected. An increasingly important use of computers as a research tool involves the construction of mathematical models that embody the essence of a researcher's theory about the functioning of a biological system. Such models not only permit the researcher to study complex biological systems but are often useful in teaching medical students.[35]

7. A recent World Health Organization review of computer use in medicine reported that there is a great need for an "electronic encyclopedia" of medical knowledge.[36] At present, the physician faced with a case difficult to diagnose generally seeks the advice of colleagues and consults textbooks; but his colleagues may not have any more extensive knowledge than he does, and the textbooks may be out of date. A medical information utility, however, could make the most recent information available.

Computers and Education

When Sputnik jarred national pride in 1957, the United States stepped up its commitment to education, and more recently has embarked on even greater efforts. Education now engages over 5 percent of the labor force (excluding students),[37] and costs in excess of $30 billion a year.[38]

As school-age population increases, as the average educational level rises, and as the philosophy of viewing education as a continuous process throughout our lifetimes is adopted, the Nation's commitment to education must continue to grow.

Most educators and psychologists agree that the present educational process is deplorably less efficient than it might be. Clearly, the computer is destined to play an important role in improving efficiency during the next decade in several ways:

1. The computer will take over much of the clerical work and information handling in education;

2. Computer technology, coupled with other technological developments, will increase the student's productivity by permitting individualized instruction. This is potentially much more important than (1) above;

3. Computers will become important tools for educational research and development and will help psychologists and educators to a better understanding of the learning process.

Let us look at each of these in more detail:

1. Since education has all the same management and administrative problems as industry, plus a few more, computer and information technology is applicable; and while education lags behind most of industry in computer utilization, it has begun to adopt computers in a major way. This will result in increased productivity among administrators as well as teachers and students and in better utilization of capital resources. As mentioned earlier, using a computer for classroom scheduling creates classroom space.[39] As in industry, increased productivity from managers and clerical workers in education is to be expected; but the impact on teachers and students is possibly not so obvious. Teachers, too, spend much time in clerical activities. For example, the Richmond (California) pilot study found that computerizing the reporting of grades added at least 4 effective teaching days to the school year.[40] Technological and economic feasibility exists for these applications today, and it is only a matter of time until they are adopted.

We can also contemplate the possibility of a terminal connected to a central computer for each teacher to aid with information processing. Such systems will soon be technologically feasible, but economics will probably delay widespread use of teacher terminals until at least the early 1970's.

2. Many of the inefficiencies of present educational systems are connected with the fact that instructors must usually deal with their class as groups and not with individual students. Should the level of teaching be geared to the slowest or the fastest learners? The great hope is that computers and technology will permit individualized instruction so that each student can work at his own pace and not proceed to new material until he has mastered the old. Not only will individualized instruction help the slow learners, but equally important, we may realize the real potential of the gifted child. In spite of all the efforts to recognize and help the gifted, much more time is devoted to below-average children.

Individual instruction is usually based on notions of programed learning. This is a controversial subject: programed learning has not, to date, lived up to its advance publicity, and simple teaching machines have been an economic failure.[41] But students can learn from programed materials; and as techniques improve, particularly with the added scope and greater sophistication permitted by the use of a computer (the system envisaged consists of student terminals with a display device and a keyboard), researchers have great expectation for programed instruction.

While some areas of instruction can be readily adapted to the computer, others are much more difficult. For example, drill-and-practice systems

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[35] J. V. Maloney, Jr., M.D., J. C. DeHaven, E. C. DeLand, and G. B. Bradham, M.D., *Analysis of Chemical Constituents of Blood by Digital Computer*, The RAND Corp., April 1963.

[36] M. S. Wilde, "Computers to Furnish World-Wide Diagnoses," *Los Angeles Times*, Oct. 7, 1965.

[37] *Employment and Earning Statistics for the United States, 1909–64, op. cit.*

[38] Gilbert Burck, "Knowledge: The Biggest Growth Industry of Them All," *Fortune*, November 1964, pp. 128–131, 267–270.

[39] "School Scheduling," *op. cit.*

[40] *A Report of An Experiment—The State Pilot Project in Educational Data Processing*, Monograph No. 3, Educational Systems Corp., Malibu, Calif., 1964.

[41] Kenneth O. May, *Programed Learning and Mathematical Education*, a CEM study, Committee on Educational Media, Mathematical Association of America, 1965.

are comparatively easy to program. Part of the computer-assisted instruction system under development by Patrick Suppes at Stanford University involves drill-and-practice in arithmetic. Five levels of difficulty at each grade level for each concept in elementary school mathematics permit the computer to present a level of problem difficulty to the individual student based on his past performance rather than giving each child in the class the same problems as is normally done.[42]

Tutorial systems, where the aim is to develop the pupil's skill in using a given concept, are somewhat more difficult than drill-and-practice systems; e.g., teaching a first grader to understand the concept of "top," "bottom," "left," "right," etc. In the Stanford system, every effort has been made to individualize the tutorial process to avoid failing culturally deprived children and to avoid boring the bright child.[43]

Concerning the future prospects for tutorial systems, Suppes says:

> . . . it should be evident from the sorts of examples I have given that the skill subjects such as reading, mathematics, and elementary foreign languages can be handled most easily and are best understood as taught in this environment. We shall be able to use tutorial systems to carry the main burden of teaching skill subjects. Widespread application would lead to a radical revision of the organization of teaching, because a rather large part of all instruction is at the elementary skill level. For this reason, it is common to ask what will be the teacher's task if these elementary skills are taught in a tutorial fashion by computer-based terminals. The most important point to be made in this connection is that no tutorial program for computers in the near future will be adequate to handle every type of problem that arises in students' learning. It will be the teacher's responsibility to move to the much more challenging and important task of troubleshooting, of helping those children who aren't proceeding successfully through the tutorial program, and who need some sort of special attention. At Stanford we have in our tutorial programs what we refer to as a teacher-call. When a student has run through all the branches of the concept and has not yet met a satisfactory performance criterion, there is a teacher-call at a proctor station, and a teacher comes to give individualized instruction as extensively as needed.[44]

Dialogue systems, in which discourse between the student and the computer system would take place in the same fashion as exists between student and teacher, will obviously be much harder to develop. The difficulties in getting a computer to process language have been previously discussed. Unrestricted (other than subject matter) dialogue systems will probably not be technologically feasible by 1975, but systems constrained to limited vocabularies and stylized syntactical constructions will be practicable.[45]

Although some areas of computer-aided instruction (CAI) are technologically feasible today, economic feasibility is another matter. For some time, CAI will be confined to experimental research and to specific areas of adult education where the cost can be justified (e.g., electronic technician training). Widespread use will depend not only on research progress, but also on the size of the financial commitment the Nation makes to education.

Individualizing instruction depends on knowing what material the individual has mastered. CAI systems must determine a student's status based on an analysis of his responses to the computer. This assessment of the student's progress determines the material to be presented next. Without CAI, the teacher will lack the time to develop and give remedial instruction to each student. However, the computer could, based on the analysis of the difficulties, instruct the student to review certain portions of the text.

3. The computer is a useful tool in the performance of research and development in education as it is in almost all R. & D. work. It permits the researcher to deal with more complex data and greater volumes of information than he could otherwise. CAI systems will be able to capture and preserve much greater quantities of data than were previously available.

Computers are being increasingly used in psychological research, both to analyze experimental data and to develop psychological theories about information processes in humans. The behavior of a computer is determined by a program, and the goal is to develop a computer program which causes it to perform an information-processing task the same way that people do. The program is a model which represents the researcher's hypotheses about the information processes underlying human cognition, just as the computer program which calculates missile trajectories represents a theory of the flight of a missile. The implications of the model are determined by running the program on the computer with varying inputs and observing the outputs.[46]

The implications for improved efficiency in our educational system stemming from a better understanding of the human learning process are tremendous, whether that understanding comes from computer modeling of human cognition or from some other research strategy.

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[42] Patrick Suppes, "On Using Computers to Individualize Instruction," *The Computer in American Education: Issues and Applications*, Preliminary papers for the AEDS-Stanford School of Education Invitational Conference, sponsored by the Fund for the Advancement of Education, November 1–3, 1965, Palo Alto, Calif.

[43] *Ibid.*

[44] *Ibid.*

[45] For an example of a dialogue, see J. A. Swets, and W. Feurzeig, "Computer-Aided Instruction," *Science*, vol. 150, No. 3696, Oct. 29, 1965, pp. 572–576.

[46] E. A. Feigenbaum, and Julian Feldman (eds.), *Computers and Thought*, McGraw-Hill, New York, 1963, pp. 269–386.

Information Processing Education. Instruction in the science of information processing itself is another important area. Since computers are playing an increasingly important role in society, it is vital that a large segment of our population understand information processing and know how to utilize computer power. Not that everyone must be a computer programer any more than we have had to become automobile mechanics, but understanding and knowing how to use the computer are important. Numerous experiments have established that computing can be learned at an early age, say the 11th or 12th grade level. Indeed, it can be argued that it is best learned at that level. However, our secondary school instructors are unprepared to teach the subject.

The computer is already a powerful tool for the college student, and the trend is clearly toward having college students learn its use. Some 500 college campuses have at least one computer. In many schools—particularly engineering schools—the students use computers for appropriate assignments. They do their own programing, punch their own input cards, and leave the punched cards at the computing center on their way to class, retrieving the output an hour or so later or the next day. Soon, computer terminals will exist at various places around the campus at many universities; several schools already have this capability. It is implicit in such a setup that the course assignments require a computer to complete them: hand calculation methods would swamp the students. The problems assigned can be realistic, rather than oversimplified models in which the answers "come out even." Oddly enough, there is not a single text—at any level or in any subject—that assumes student use of this new capability, but they are surely to come.

The movement of computers into the schools has been slow and haphazard, but it will be speeded up as low-cost but powerful machines and time-shared terminals offer the schools economical and vast computing power.

V. The Social Implications of Computers

When things change rapidly, it is convenient to talk in terms of "order of magnitude," meaning a change by a factor of 10. It is commonly observed that a change of an order of magnitude in a technology usually produces fundamentally new effects. For example, man can travel on foot at speeds around 4 miles per hour, or move by automobile at 40 miles per hour, or by jet plane at 400 miles per hour. Thus, the automobile is one order of magnitude faster than walking and the jet plane two orders faster. These changes have brought about fundamental changes in our way of life.

Computer speed has improved by at least 7 orders of magnitude over hand calculations—a 10-millionfold increase. At the same time, the cost of operation has decreased by something more than 10,000 times, or 4 orders of magnitude. And changes in computer technology are still taking place. Speed increases of one or two orders are now available in the laboratory, and at least another order decrease in cost appears likely when these devices reach the market. It is reasonable to expect that 1975 will compare with the precomputer era by 10 to 12 orders of magnitude in speed (or a thousand billion) and by 6 to 8 orders in cost.

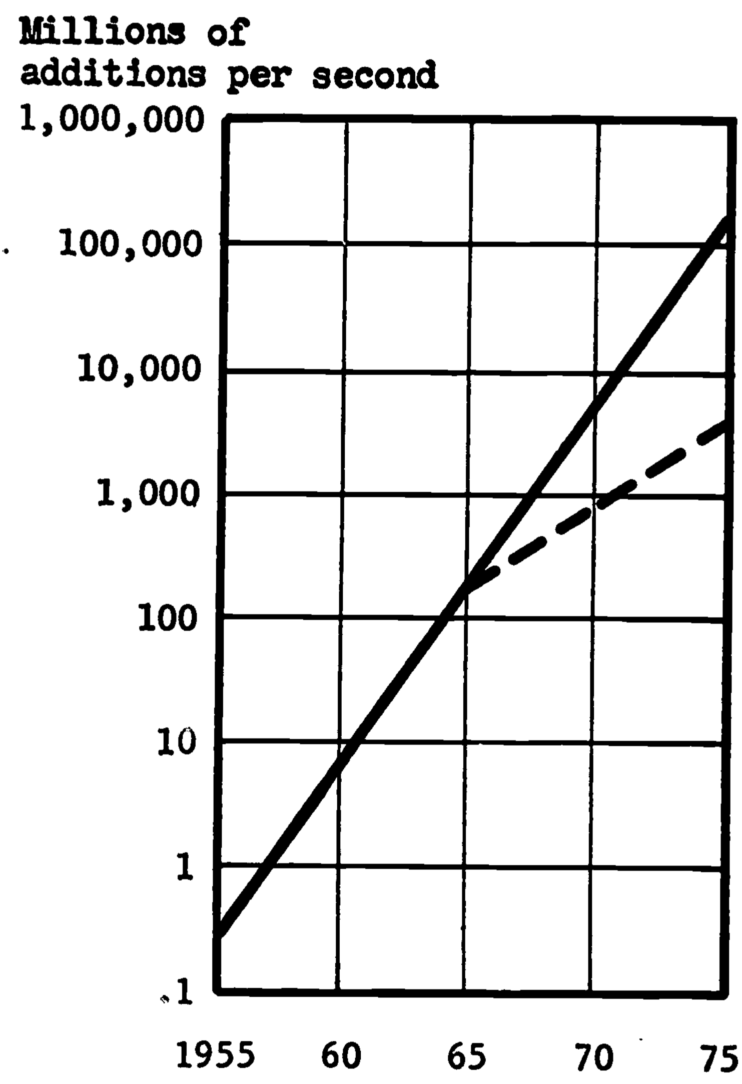
Figure 4 represents the amount of computing power available in the country. So far, it has been doubling each year; i.e., it changes by an order of magnitude in a little over 3 years. Experts disagree about whether it can continue at that rate, but I believe that it will through 1975. (The broken line in fig. 4 is a more conservative curve, representing a 70 percent rather than a 100-percent annual increase.)

Thus, significant changes in our way of life should be anticipated in view of the expected changes in speed, cost, size, and amount of available computer power in the Nation, and because of the factors discussed earlier, such as the development of information utilities, pictorial processing, language processing, better and varied input/output devices, and improved ease of use.

Increases in human productivity are to be expected, although the improvement will not be uniform. The overall impact of computers and technological change should result in an even higher rate of growth in productivity than the economy has enjoyed in recent years. Some types of jobs will disappear, many will change, and new ones will be created. Education, government, industry, unions, and individuals must expect and plan for continuing change, which will become an increasingly important factor in life. Many individuals will have to learn and perform two, three, or more different types of work in their lifetime, and education must be accepted as a continuing, lifelong process. This will be especially true for people in professional and technical occupations. Those who are unable to adapt to change will find life difficult.

In many fields significant changes are taking place well within the period of an individual lifetime. It used to be that a man could go to school, take a job in a profession or in industry, move up in the organization, and do his job well until retirement, drawing on what he was taught in school and on what he learned through experience. In many fields, including business, this is becoming more and more difficult. Without continuing edu-

FIGURE 4.—*Computing Power in the United States*



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cation in new developments, an individual may find himself obsolete. Many companies are even now hiring specialists fresh out of college at the same time that they are terminating older men in the same specialty or restricting the number of older men they will hire. Organizations get into trouble because top management has not kept up with technological change, and individuals are frightened because they know their knowledge and experience are out of date.

Employment

No other social implication of computer utilization receives so much attention as the impact on jobs. When productivity increases faster than demand, people are displaced. When increase in demand matches increase in productivity, no one is displaced, but "silent firings" result as fewer new jobs are generated. More new jobs must be created elsewhere by overall growth of the economy.

A broad analysis of anticipated increases in productivity is beyond the scope of this report, but needless to say, they will be greatest in activities involving simple processing of information. (For this reason, attention was focused earlier on banking and government.) Let us consider several classes of workers in such activities.

Office Workers. Computers have often been economically justified on the basis of the number of clerks they will replace, yet the percentage of clerical and kindred workers seems to have remained constant over the years. There has been speculation that computers and office automation have retarded growth in white-collar jobs.[47] Yet in 1964, the gain in white-collar employment (3.1 percent) was greater than the gain for all nonfarm employment (2.7 percent) and the gain for clerical and kindred workers was higher still (3.9 percent).[48]

On the other hand, the managerial work force has lagged behind all other white-collar subdivisions in rate of growth for some years and declined in 1963; 1964's gain was 2.2 percent.[49] Since electronic data processing greatly affects the productivity of middle management, it must be assumed that computers have had a role in the declining growth of managers—though to what extent is another matter. This occupational category includes proprietors, and some of the decline may be attributable to the trend toward formation of larger businesses with consequently fewer proprietorships.

[47] Ted Stanton, "Office Automation: New Devices, Systems Bring Sharp Slowdown in White Collar Hiring," *Wall Street Journal*, May 5, 1964.
[48] *Manpower Report of The President, op. cit.*
[49] *Ibid.*

Despite a declining growth rate for managers and increased productivity among both clerks and middle management, the ratio of unemployment in each group to the national unemployment rate has remained almost unchanged over the last decade at 0.7 for clerical workers and 0.3 for managers.[50] However, data in table 1 could indicate that young girls, particularly in the past 2 years, are having an increasingly difficult time in finding employment. If "silent firings" mean that they are unable to find that first job as a clerk, then they never become classified as an unemployed *clerk*.

TABLE 1. RATIO OF UNEMPLOYMENT RATE AMONG YOUNG FEMALES TO NATIONAL UNEMPLOYMENT RATE, SELECTED YEARS

Age	1953	1959	1962	1963	1964
14–19	2.40	2.24	2.35	2.75	2.88
20–24	1.48	1.47	1.62	1.56	1.65

SOURCE: 1953–62 data from R. A. Gordon, "Has Structural Unemployment Worsened?" *Industrial Relations*, vol. 3, No. 3, May 1964, pp. 53–77; 1963–64 data from *Manpower Report of the President*, U.S. Department of Labor, March 1965.

Over the next decade, as available computing power continues to grow exponentially, as input/output devices become more elaborate, as computer applications become more sophisticated, as management information systems come into being, and as duplication of effort is eliminated, I believe that middle management, and especially clerical positions, will decline as a percentage of total employment. Increased productivity will have more of an impact on employment in industry than in areas of increasing demand for services (e.g., government and medicine).

Clerical functions of secretaries, stenographers, and typists will be affected in the manner previously discussed, while service aspects of their work will be affected only slightly. With typewriters as terminals on a computer utility, productivity will be increased by reducing retyping to a minimum, and some letters could be composed from paragraphs prestored in the computer. Because of difficulties in voice recognition, I do not anticipate the development of a voice-operated typewriter by 1975.

Professional and Technical Personnel. The productivity of professional and technical personnel can be expected to increase significantly in the coming decade because of information utilities and the availability of inexpensive, easier-to-use computer power. Information utilities will make the work of others more readily available. However, in our increasingly technological society, the need

[50] R. A. Gordon, "Has Structural Unemployment Worsened?" *Industrial Relations*, vol. 3, No. 3, May 1964, pp. 53–77; plus updating through 1964 in *Manpower Report of the President, op. cit.*

for professional, scientific, and technical personnel should continue to grow at a rate faster than the total labor force. This is not to say that professional and technical personnel will not be displaced at times, particularly those involved in increasingly automated design and testing functions. But when displaced, they should be able to find other employment if they have not neglected their continuing education.

Draftsmen. Draftsmen and related occupations should decline after 1970 as the result of the increasing ability of computers to process images and drawings and the introduction of automated design techniques coupled with computer-controlled tools and processes. Even simple systems in existence today can produce detailed construction drawings 25 times faster than a draftsman.

Typesetters and Compositors. As discussed under publishing, these occupations are dying out.

Machinists. Numerically controlled (N/C) machine tools can not only turn out work faster than men (from 10 to 100 times as fast), they can produce work to better tolerances and with less spoilage. However, of all machine tools installed today, less than 1 percent are N/C; and in 1964 N/C sales accounted for about 10 percent of the total dollar volume. Although there have been dire predictions of gross displacements in the future, it would seem that even by 1975 the majority of machine tools will still be manually operated. Although the total number of machinists may actually decline, this occupation will continue to provide a large number of jobs in the next decade.

Sales Personnel. Large-scale machine-vending of goods is not expected to materialize by 1975, although its use will increase. By 1975 some sales will be made from a catalog via an information utility. Nonetheless, the customer's desire to touch and see and ask questions, coupled with the seller's wish to have a salesman to push his goods will require sales personnel. Their productivity will be increased by a reduction of clerical functions (e.g., taking inventory, making out sales slips, etc.). Better inventory control will reduce investment in goods and insure that what the customer wants is more often in stock. Sales-reporting systems via telephone for salesmen on the road will speed up the ordering process and result in better service to the buyer.

Employment in the Information Processing Field

Although information-processing equipment has displaced workers in some fields, a whole new industry has developed that provides several hundred thousand new jobs. Already a multi-billion-dollar industry, sales in the information processing field have been growing at a rate of 25 to 30 percent per year, and there seems little doubt that a 15- to 20-percent growth can be maintained over the next decade.

Statistics exist only on production workers for the manufacturers of computers and related equipment. In 1963 about 100,000 were employed, an increase of 23 percent over 1958 but a decrease of 1 percent from 1962.[51] Because of increasing automation, this number will probably continue to decline despite rapidly increasing sales. One manufacturer predicts that by 1967 his direct labor costs will approximate 1 percent of his sales price.[52]

Sales and service personnel will continue to increase at a rapid rate as will those involved in analysis, programing, and operation of equipment. The number employed in these occupations today is estimated between 200,000 and 350,000. Analysis—deciding what the computer is to do and designing appropriate procedures—will grow the fastest in the next decade. By 1970 the numbers of people engaged in analysis may be three times what it is today. Next fastest will be programing—writing out the instructions for the computer. This function will be increasingly carried out by the computer itself so that the number of programers will not grow as fast as it has in the past. However, it will likely double by 1970.

On the other hand, the function of computer console operator will almost cease to exist in the computer utility of tomorrow, and consequently their numbers can be expected to increase only through 1970 and then level off.

One of the jobs created by office automation is that of keypunch operator, and the demand has never been higher than it is today. The use of optical character-recognition devices, the capturing of data at its source, computer-to-computer communication, plus other factors leading to better productivity, should eventually cause the growth of keypunch job opportunities to level off. Over the next 5 years, however, continued rapid expansion of computer use should offset jobs lost to mechanization. Thus, while keypunch operators will often be displaced by a machine, they will be able to find jobs elsewhere; whether this will be the situation in the 1970's, however, is a matter of disagreement among the experts.

Computers and Privacy

As we go through life, we leave behind a trail of records. The first is our birth certificate, followed by medical records and then educational data, in-

[51] "DC Output: From Our Man in Washington," *Computer Design*, September 1965, p. 8.
[52] Max Palevsky, "Tomorrow's Data Processing and Computers," *Interface 4*, Scientific Data Systems, speech given at Institute of Management Sciences, Los Angeles, Calif., Apr. 30, 1965.

cluding grades, behavior, IQ-test scores, and personality profiles. We may spend some time in the military service. We obtain a social security card and start a history of employment records. We get a driver's license. Some of us will receive traffic citations, and others may have police records for more serious offenses. The list is endless.

Today, these records are widely dispersed and generally inaccessible in their totality without a great deal of effort and diligence. The price for putting together a complete personal history of an individual, even with his cooperation, is very high; without his cooperation, it is tremendous. In the future, it is likely that such information will be centralized and easily accessible, at least to some. Unless appropriate precautions are planned now, an unscrupulous individual would be able to turn up scandalous and defamatory information, where it exists, with comparative ease.

Up to the present time, it usually has been possible for an individual to escape his past. But with computerized information services, if one ever runs afoul of the law as an adult, does poorly in school, has a poor credit record, or suffers a heart attack, the records will be comparatively easy to get at. From some viewpoints, this may be socially desirable, but the basic question is the wisdom of having all aspects of a person's past life a completely open book.

If society regards such a lack of privacy as unacceptable, then safeguards must be built into our information systems. We suffered many fires before adequate electrical codes were developed. Let us hope that we can be wiser this time and incorporate adequate safeguards into the information systems now under construction. Paul Baran suggests a number of specific safeguards in *Communications, Computers and People*.[53] Donald N. Michael discusses the problem in detail in "Speculations on the Relation of the Computer to Individual Freedom and the Right to Privacy."[54]

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[53] Paul Baran, *Communications, Computers and People*, The RAND Corp., September 1965.

[54] Donald N. Michael, "Speculation on the Relation of the Computer to Individual Freedom and the Right to Privacy," *The George Washington Law Review*, vol. 33, No. 1, October 1964. pp. 270–286.

COMMERCIAL INFORMATION PROCESSING NETWORKS—PROSPECTS AND PROBLEMS IN PERSPECTIVE

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CONTENTS

Commercial Information Processing Networks—Prospects and Problems in Perspective

1. Current Status

Information Processing Networks (IPN)

The electronic computer is gradually becoming a common and major ingredient of all our traditional communication and information systems. Rapid developments during the past two decades have yielded a computing technology with present capabilities that would have staggered the imagination of early pioneers in this field only 20 years ago. There is little reason to expect that anyone now can foretell developments during the next two decades even as clearly as was possible 20 years ago.

A current development that promises to be of great importance and one that represents a dramatic advance over the past 20 years is the rapidly increasing worldwide capability to give ready and economical access to many computers to nearly any organization or person seriously needing such a facility. Indeed, subject only to making necessary business arrangements, several computers are already available to anyone with an ordinary telephone. Those with a teletypewriter on the telephone system have all the equipment necessary to make full and effective use of several major computing installations in the United States.

At least one of our largest manufacturing corporations operates an internal network that makes it possible for each of its offices equipped with a teletypewriter to use several company computers at various points in the country. The interaction between the person at the teletypewriter and the remote computer is essentially instantaneous in both directions, with the user receiving exactly the same service were he at the computer. The only additional expense due to distance from the computers is the marginal cost for increased use of the regular voice communication system operated for the corporation by the telephone company.

Several commercial services throughout the country make it possible for any subscriber to have access to one or more large computers with charges based directly on the amount and nature of the use made of the facility. In this sense, the computing service is essentially the same in principle as the various kinds of voice communication service provided by telephone and telegraph companies. The quantity and quality of such information processing services will certainly increase rapidly and dramatically in the immediate future. It seems reasonable to expect that charges will decrease as volume increases and technological costs are allocated among many users.

Data Transmission Facilities

The central computing equipment and communication lines and switching systems that make this information processing network system physically possible are already in an advanced state of development. Frederick Kappel, chairman of the board of the American Telephone & Telegraph Co., stated recently that his company expects the volume of data transmitted over their system to exceed the volume of voice transmission before 1970, and capital expenditures are being allocated to include support for these anticipated rapid developments. He also noted that the touch-tone telephone can and will be used in the near future as a terminal for sending instructions to remote computers, with synthetic voice return from the computer to convey requested information back to the user.

As an example of the forces pulling against more rapid progress, however, Mr. Kappel also remarked that his company is converting all present electromechanical central offices to electronic operation soon, at the rate of about one new electronic office in service every working day, but that this modernization and changeover will even then not be completed until after the year 2000. Nevertheless, on balance, it would seem that nearly any kind of physical facility required for future operations of information processing networks can be developed and acquired, subject only to timing and cost.

Newer advances, such as communications satellites, are of great importance in meeting the expanding need for information transmission channels. Even a relatively slow transmission channel like that provided by modern air transportation is of great importance, especially because tremendous quantities of information can now be reduced reliably and usefully to digital form for compact storage on magnetic and optical media. The cost for transmitting this tremendous volume of information, stored compactly, is quite negligible in comparison with past years.

Rapid transportation for transmitting compactly stored information brings every receiving location within only a few hours of every transmitting location throughout the world. For many purposes, this type of rapid air transport will be quite adequate for transmitting information in the tremendous quantities that will be required. All of these information transmission methods are made feasible by the existence of computers able to transform information stored digitally and compactly into many other forms, including ordinary printed pages.

Software

Important as are the technological developments in equipment for information processing systems, the entire development would be relatively unimpressive were it not for the equally rapid advances in concepts and procedures for managing and operating such information networks. It is already common practice to assume that the cost of "software" (i.e., concepts and procedures supporting the physical system) will be roughly equal to the cost of "hardware" (i.e., equipments and facilities actually comprising the physical system). Although experience with software for information processing systems and networks is still relatively limited, it seems safe to assume that essentially any kind of software required for future operations of information processing networks can be developed and acquired, subject again to timing and cost.

File-Sharing

Perhaps most significant for understanding the present major advance in making information processing systems generally available is that it is possible, for the first time, to store tremendously complex concepts and procedures developed by one group and make them available immediately to many others; that is, providing only that the command language for directing the information system is made available to other potential users. This intellectual sharing is accompanied by an almost equally important sharing of large files of accumulated information, where access to the command language of and physical channel to the file represents a key that not only makes the concepts and data available but also provides protection against unwanted access.

Multiuser Time-Shared Computers

Excellent discussions of the concept of commercial information processing networks, including estimates regarding present and future technological progress, have been published by various authors. Project MAC results at MIT typify the present state of the art and thinking regarding the "computer utility," as it is called at MIT. Robert Fano, director of Project MAC, has written about both the technology and the social and economic implications in several published articles and in testimony before congressional committees. John McCarthy, now at Stanford University but formerly at MIT, is credited with early recognition and discussion of the computer utility possibility, and has contributed both to the technological advance and to the discussion of social and economic implications. The Project MAC computing system now in operation services many users through out the country and is viewed by MIT as an experimental prototype for a commercial information processing network. This system and a similar one under development at the System Development Corp. provide principal examples on which to form judgments about the future of such information networks.

Arthur Samuel of IBM and MIT has recently published an article describing existing time-sharing computing systems. Computer Research Corp. has published a census of such systems, and the Association for Computing Machinery has established a committee to report on developments regularly. A group at the Harvard Business School has completed a study of existing time-sharing systems and plans for future commercial information processing networks, and will soon publish their data and findings. The Harvard study obtained interesting responses to a questionnaire designed to assess the future social and economic impact of commercial information processing networks.

Artificial Intelligence Research

There are many important special developments of information processing networks and of relevant projects to solve basic intellectual problems already recognized as essential for understanding present and future developments of such systems. The National Science Foundation publishes an annotated list of such projects about once a year, and these many projects provide a further basis for assessing prospects for the future of the developing information processing networks.

2. Special Projects (IPN)

Library

Important among special projects are several concerned with the modernization of libraries and the national library system. The Library of Congress has begun a major project for the utilization of computers and information processing to serve its users. The National Library of Medicine is operating a bibliographic and reference system, called Medlars, that is already serving biomedical institutions throughout the country. The University of California, MIT, and the University of Michigan, among other major educational institutions, are undertaking ambitious projects for the modernization and improvement of their libraries, including continuing fundamental research in addition to immediate installation of equipments and procedures.

The Office of Science and Technology has chosen the biomedical library network problem as a first major undertaking in a program to assess the importance of advancing information technology in terms of repercussions for Federal administrative and legislative action. There is an immediate question faced by the Congress and the country regarding the extent to which traditional major libraries are appropriate for the future in competition with information centers making relatively minor use of books and other graphic materials in conventional form. For example, should substantial funds be dedicated in the future for construction of traditional library buildings, or should they instead be used for newer types of information storage and retrieval centers?

Educational

There are many substantial efforts to develop information processing networks in connection with a variety of educational and training functions. For example, IBM has a cooperative program with several universities: each campus is developing educational computer programs locally which are operated by remote communication with a central computer in New York. One user is in California, another in Pennsylvania, and others elsewhere, all using the same central files in New York. Each participating institution is developing its own special computer programs using terminals operated locally by individual students and faculty members. Various other networks are under development for educational purposes, including several within industrial corporations to be used for training employees in a variety of standard tasks. As with the library information network movement, many projects and individuals are concerned with research both on the technology and the social and economic impact of such systems.

Biomedical

Past progress in the development of information processing networks will be important for medical practice and hospital management. It is already possible to use a teletypewriter anywhere on the commercial telephone and telegraph system to interrogate a computer in Boston and obtain results relevant for hospital management or medical diagnosis. This is all on an experimental basis at present but is moving ahead satisfactorily under joint sponsorship of the Massachusetts General Hospital and Bolt, Beranek, and Newman, Inc. Although not yet intended to serve users outside of the participating hospital, it is quite apparent that most of the software and much of the data can be utilized easily in any other similar biomedical information processing system. It is significant also that users anywhere can also make direct contributions to this system from their own computer terminals no matter how remote from Boston.

Various authors have speculated that eventually a physician located almost anywhere will be able simply to pick up his telephone, query the biomedical information center best equipped to answer his question, and quickly receive a reply. Difficult questions of considerable importance in diagnostic considerations could be posed, with the answers reflecting records of similar cases drawn automatically by the computer from its files.

While no substantial biomedical data files and procedural systems are yet available for routine use, it is only a matter of time, attention, and the completion of several developmental projects already under way before primitive systems of this kind will be in regular operation. Indeed, in the more distant future it may no longer be important for a medical practitioner to present his experience and conclusions at medical meetings or publish them if this kind of information can be made more universally available and usable simply by adding his increment to the central biomedical files.

Automated information files can be kept current and updated more readily than is possible with present publication and lecture processes. Many authors have stressed that central files will greatly increase the accuracy of diagnosis and quality of care for patients who change physician or hospital or residence. Researchers and medical students can also easily be given direct machine access to these files.

Engineering

Perhaps the most impressive current example of effective interaction between man and computer is represented by the engineering design DAC I system developed jointly during the past 5 years by the General Motors Corp. and IBM. For the past 2 years GM has made systematic use of the DAC I system in styling automobile bodies, but these are just now beginning to affect production models.

GM's styling experts are changing their methods now that the new tool is available, a common occurrence where automation makes possible radically new approaches that often could not be conceived of previously.

Project MAC at MIT is another example of the use of information processing networks for engineering design purposes. The Project MAC network is used by research engineers, faculty, and students in nuclear reactor and naval vessel design, and in several civil engineering design programs still in an early development stage. Software is critically important, and design data and principles must be made available to the designer simply and in a command language with which he is already familiar. It has been conjectured that design engineers anywhere in the world will, in the not too distant future, be able to pick up a telephone and query any of several central engineering information centers. It is now possible for authorized persons to interrogate the Project MAC system by teletypewriter and use any of the engineering design programs.

Legal

Members of the legal profession and computer technologists have jointly studied possibilities for automatic data processing in legal matters. Some private firms are already reducing statutes and cases to digital form for compact storage to be used eventually in systems designed to answer legal questions.

Many look to the day when every lawyer will be as near as his telephone to any of several central legal information files which he can interrogate directly to receive immediately information and analyses on legal questions. Hopefully legal facilities of this kind will help reduce the backlog of cases now clogging our court system, a delay caused to a great extent by the need to search existing files in the preparation of briefs which automatic data processing systems can do efficiently and economically.

Legal information networks might also be interrogated even during trials; the need for complete preparation of evidence in advance would be reduced, since the essence of every decision process is a sequential set of steps that lead eventually to an answer to the basic question.

Product

Management of product distribution and inventories, on which the computer has already had an impact everywhere, should also be greatly influenced worldwide by developing commercial information processing networks.

In the past, otherwise unnecessarily large inventories were commonly maintained simply because of the great difficulty in keeping detailed records adequate to ensure the availability of all items when needed. Automatic data processing systems have made this tremendous recordkeeping task more manageable. Together with recent conceptual advances in the theory and practice of inventory control, this new tool has enabled manufacturers, distributors, and consumers to reduce inventories without endangering their operations due to shortages that might previously have occurred. Up to now these developments have not extended much beyond recordkeeping and determination of quantities for purchase and stocking. Placing of orders and transfer of funds due to the transactions continue to be made in traditional fashion. However, the future impact of information processing networks should greatly reduce paperwork.

The commercial information processing network will be used extensively for advertising and sale of products and services. When the cost is small for a query of the system, vendors will come to depend upon user inquiries to meet demands for desired products. Obviously, the network must be impartial with respect to inquiries so as not to favor any particular vendor. An inquirer will be able to direct his question specifically to particular, favored prospective vendors. The user will also be able to arrange to receive further product information by mail, and the network will make advertising and promotional information available when the inquirer wishes. In many cases the inquirer will be able to receive visual information regarding the product or service as visual displays become more economical and therefore more widely available; this will be possible in the near future, especially at central purchasing points where inquirers can come for this more complete service.

Important is the ability of a computerized information system to keep records easily on transactions it performs. Network inquiries leading to sales will provide internal data important for analyses of product markets. These analyses should eventually lead to a much more effective and efficient system for bringing vendor information reliably to purchasers; competitive vendors must each strive to find the most effective packaging for their information, and purchasers can learn of the general reaction of the market to products and services offered. These new analytical capabilities also raise difficult questions regarding access to the system for these purposes, with protection of the network's users a necessity.

Financial

Perhaps the first major use of a commercial information processing network is for the sale of stocks through brokerage houses throughout the country. Detailed information regarding current market status of any of the listed stocks at many brokerage houses is available visually, printed on paper tape, or sometimes returned by voice message. Thus, a broker's customer may operate a simple console and receive almost instantly useful and detailed information regarding the market. Although not now the case, it would in principle be possible to record these inquiries and use the information in analyses of market behavior.

Voice responses seem likely to be the most prevalent type of return from the information processing network during the next few years, only because this system already exists and is much more economical than presently available visual display. The capability to get a prompt voice report of time, weather, or various other factual matters by telephone in nearly every city is familiar to everyone. The generalization throughout the telephone system of the capability to make a sequence of inquiries based upon answers to previous questions from the same computerized information source will be significant in making available to the public substantial and sophisticated commercial information processing.

Sequential interrogation for simple information can most obviously and directly be extended to induce logical manipulation and numerical calculation in application to stored information files. The operation of remote computers from teletypewriters is a current example of this kind of sequential query and command system.

Thus, with sequential query and command processing, a vendor will be able to ask the system if a customer's bank balance is adequate to cover the cost of a proposed purchase before the sale is made and the customer's own console entry in payment to complete the transaction is accepted. Presumably, such summary balance information would be readily available, having been produced by numerical processing by the bank. In other cases, the network system might have to make quite elaborate calculations before responding to the inquiry. A number of persons have proposed that many kinds of financial transactions will soon become a major feature of a national financial data processing network. Such a major financial system is also likely eventually to be a part of an even larger system for processing other kinds of information.

Transportation

Many information systems are a part of some large operation, perhaps on a national or international scale, that will be dramatically affected by the availability of a commercial information processing network. An example is the information processing operation needed in transportation management to keep an operating record adequate to guide individual haulers to the point of pickup and destination. A large number of highly experienced personnel are required to process requests and decisions regarding transport of all types of loads by all types of vehicles. These range from initial planning of transportation means and routes, including costing of alternative solutions, to maintaining delivery records, and eventually completing agreements by financial transactions of various kinds. Several major transportation organizations are already installing or considering private communications and processing networks on local, regional, and national bases. This type of information processing network development is not likely to be able to proceed efficiently from a national standpoint unless much more careful planning is done and more sensible direction is given from an overall standpoint. Again, there are very difficult problems in designing such systems to protect users from misuse.

Implications and Impact

Here, then, are a few of the exciting prospects for commercial information processing networks. We have indicated these prospects only for a few of the many fields that will be dramatically affected by future developments. Our examples typify the kind of function and advantage that results from the availability of commercial information processing networks operating on a substantial scale.

The national library system example, including information center networks such as that in the biomedical field, supports the hope that the world's vast store of knowledge may eventually be made readily available on a current basis to nearly everyone. The sharing of educational courses and materials by access through national and regional educational networks should not only relieve some of the strain on classrooms but promises also to bring the best of instruction to students everywhere.

Biomedical research, the practice of medicine, hospital management, and public health operations will improve through use of shared data files and through cooperative exchange of important computer programs as networks develop and make such information accessible. Computerized information networks will also be invaluable in many fields of engineering, both in the practice of engineering design and in research important for the engineering sciences.

We are seeing the beginnings of the use of commercial information processing networks in special fields of law. Many authors are predicting that this new technological development for law will greatly reduce the burden of legal analysis because of timely cooperation by members of the legal profession in making their experience and cases available to each other through network facilities.

The new impact of commercial information processing networks upon management of product manufacturing, sales, and distribution, is a direct extension of the already great impact upon these activities by prior generations of computers.

Perhaps the banking and financial communities are moving most rapidly to take advantage of the capabilities of commercial information processing networks, beginning with local systems that serve several firms but moving soon to regional and national systems serving many, many firms. Indeed, some authors predict that these technological developments in the financial community will lead to radically different kinds of financial transactions; these may reduce lags in present transactions enough to increase financial liquidity and transaction rates to the point where the economy itself may be altered significantly.

A powerful mixture of modern communications and computerized information networks is making possible the efficient management of regional and national transportation systems. It is quite evident that similar major developments will occur during the coming years in major industries other than transportation; the effects are already discernible throughout the communication system from satellite system management down to the telephone central exchange.

There is slow but significant progress in the development of information networks that can be queried sequentially on the basis of responses to queries. This feature of information networks will undoubtedly become increasingly important as the general public becomes familiar with its potential and demands more and more service of this kind.

These few examples are intended only to establish the claim that future prospects for commercial information processing networks are indeed of major importance and are already in an advanced state of technological development. We turn next to a discussion of some of the major technical-economic-political-social problems that require attention if these networks are to develop rapidly enough and with maximum benefits for everyone.

3. Problems and Needs (IPN)

Computer Technology

Many technical problems must be solved before commercial information processing networks can develop to the extent anticipated in the previous section.

A recent study sponsored by the National Academy of Sciences under the chairmanship of Barkley Rosser provides an excellent survey of technological developments involving computers. The Rosser report stresses the use of computers in education and scientific research, and while it says little about regional and national information processing networks, it portrays the state of the computer art as of a year or so ago.

For present purposes, we shall assume that advancing computer technology will gradually solve the problems stressed in the Rosser report, important and difficult as they are. Thus, information processing networks will be increasingly more powerful and economical, and such technical matters as the development of programing languages and the production of algorithms and heuristics will continue to proceed dramatically.

We also adopt the now somewhat common principle that forecasts for technology will be optimistic for the near future but pessimistic for several years ahead. Specifically, we anticipate that no technological problem clearly conceived now will remain important for more than a decade. Of course, these assumptions do not imply the inevitability of technological advance, but only its possibility at this rate if we devote our energy and resources to that end. We certainly must select among the many possible technological directions since our energy and resources will always remain limited.

System Economics and Organization

Another class of technical problems is concerned more with system economics and system organization than with the development of more powerful hardware and more versatile software.

Recent examples of networks where organizational and economic systems problems have been solved with varying degrees of success are provided by air reservation systems, such as the SABRE System of American Airlines, and various military command and control systems, such as the SAGE air defense system. The systematization of operating procedures suitable for use with a major network is itself a very substantial technical problem. This has been demonstrated by experience with existing military and industrial networks. These networks also present technical problems of many kinds, especially when the network provides entirely new functions and services rather than a mere extension or mechanization of earlier operations.

Fortunately, a great deal of experience has been gained since World War II in the management and development of very complex man-machine systems. Although much of this experience has been with major weapons systems and more recently with space systems, the American Telephone & Telegraph Co. has been dealing expertly with complex communications systems for an even longer period of time. Industry now has a very substantial capability in the systems approach. Thus, there is every reason to expect that complex regional and national information processing networks can be designed and developed economically and efficiently by industry and cooperatively through governmental agencies.

Not until recently would consideration of economic and social aspects in designing communications systems and information processing networks have been considered a technical problem. This change in view is not due merely to recent experience with management and design of complex systems but rather to the emergence of a considerable body of systematic knowledge and techniques that can be used by systems engineers.

Systems Approach

Most of our universities now offer courses, and some grant advanced degrees, in specialties that form part of the systems engineering approach. These courses are offered under programs called, for example, systems engineering, operations research, management science, benefit-cost analysis, cost-effectiveness analysis, systems analysis, computer sciences, and communications sciences. They are often also offered within traditional engineering departments as specializations within some older discipline, such as industrial engineering or control systems engineering. Only very recently have universities been graduating substantial numbers with advanced training in these systems specialties. There has also been a very significant outpouring of basic research papers of importance for the foundations of systems methodology, and many professional groups publish journals and monographs dealing with various aspects of the systems approach.

Perhaps the most widely publicized success in the use of the systems approach to major management problems has been the cost-effectiveness work throughout the Department of Defense under Secretary McNamara and Assistant Secretary Hitch and their colleagues.

The systems approach has provided a new technology for treating complex systems matters from the standpoint of economics and efficiency—complementing the more traditional engineering approach for developing systems that perform according to chosen specifications. There has been no corresponding technological advance of any consequence in dealing with the critically important problem of matching complex systems to social needs and in harmony with political realities.

At present, those who previously applied systems methodology to military and aerospace problems have been seeking to adapt these techniques to major social problems. The current overt attempt by the State of California to hasten this transition by contracting with aerospace firms provides an important example of this trend, as do similar efforts at the Federal level in education, health, natural resources, environmental pollution, urban development, and elsewhere. But nowhere has there yet been any significant advance in developing technological means for dealing systematically, expertly, and directly with the social and political aspects of such major social problems, great as is the need. Of course, economically efficient system design and management helps indirectly in meeting social and political goals.

The greatest barrier to the development of socially desirable commercial information processing networks may well be the lack of adequate systems methodology and systems management experience to match social goals against technological alternatives and political realities. An equally great barrier is natural human resistance to change, especially when basic human value structures seem to be threatened.

Benefit-Cost Analysis

We are quite unable to estimate even crudely the social value of benefits from improved health and prolonged life that might result from biomedical information processing networks. Some progress might be made in the immediate future in estimating the direct effect on health and longevity by specific networks of this type, assuming they are politically and socially acceptable. However, there are no methods adequate for estimating the degree to which such a major innovation would be accepted and used by the health profession and general public. Nor do satisfactory scientific or technical methodologies exist for investigating the political feasibility of such proposals.

It is very difficult to evaluate existing legal structures and social customs. It is even more difficult to devise systems that would induce planned social change. Of course, many social scientists and legal scholars are deeply concerned with such problems, but their methodologies have not yet been found useful in the design and management of complex social systems. A few of these benefit-cost analysis problems will be discussed in more detail, for even though they cannot be treated satisfactorily by technological methods available at present, they must be resolved eventually.

As difficult as it is to estimate anticipated social benefits and related costs for proposed alternative networks, the task is unavoidable since the choice must be made. No such estimates will be offered here although very general statements are made about possible benefits and likely costs. The need is great for governmental action that will lead rapidly to a benefit-cost analysis capability adequate to treat such complex systems problems.

Data Storage and Transmission

Commercial information processing networks can develop only to the extent data transmission is made possible by the communications network. Telephone and telegraph lines, microwave channels, and transmission using satellites are some of the forms of links within the total communication network. Since system and links were designed primarily for two-way transmission of messages between pairs of individual users, not too surprisingly these channels and the switching systems that control them are not always ideally suited for the purposes of information processing networks. The communications industry is aware of this problem and is taking many important steps to expand and modify the communications system to make it more economical and better suited for data transmission. However, most of us directly interested in more rapid advancement of information networks believe that attention being given to this vitally important problem is completely inadequate, and that the lag in developing ideal data transmission facilities is delaying network progress substantially.

The American Telephone & Telegraph Co., Western Union Telegraph Co., and other firms in the communications industry are faced with many difficulties as they consider alternative developments and operations for a future with computers as major users of communication links. Present rate structures and communications regulations are often unsuited for data transmission as a principal operation; yet designers of complex information networks must anticipate future rates and regulations and consider these very seriously in the design of any new system. Should estimates of future regulatory actions turn out badly, then a system may be grossly inefficient and costly from every standpoint. This problem is circular and therefore especially difficult: Future rates and regulations affect system design, but the types of systems actually placed in operation play an important part in determining rates and regulations. There is an urgent need for persons with great expertness in data transmission matters at policymaking levels in both Federal and local governmental agencies, especially in regulatory agencies affecting information network development.

An example of a major technical problem in the communication area may help clarify the nature of some of these difficulties. In the past, when two-way voice interaction was the primary function made possible by the telephone system, it was sensible to base charges on the amount of time a line of a given length was temporarily made available for an exclusive use. At least the users attributed this property to the system, even though a channel might actually have been shared concurrently with others. The lines and switching systems in the telephone network have been developed to make this type of two-way, instantaneous verbal interaction possible. However, these are not at all the properties that may be most important when communication channels are being used within an information processing network.

A user of the information processing network may often start to interact with the network by inserting a message which is subsequently processed by a computer; the computer, in turn, determines which portions of the request will be transmitted to various other processors in the network. This hierarchical processing may be repeated for several stages, and eventually return information to the user without informing him of the nature or location of steps that occurred to process his request. Since the network will be serving many such users simultaneously, each processing station will, of necessity, need a buffer memory for storing incoming messages temporarily for later processing or for transmission elsewhere, according to instructions contained in the messages and priorities for processing assigned by the user or system. By storing incoming messages until they can be handled and forwarded most efficiently, the entire system improves its response rate and processing capacity. But the rate structures, the storage and switching mechanisms, and the basic network must be quite different for this type of information processing network from those for existing voice communication operations.

There are many technical difficulties in developing such multiprocessing systems even to serve a few users, like those now being developed as extensions of major time-sharing, online computers. The managers of multiuser online computers are just now attempting to find systems for charging for use that depend properly upon amount of processing, use of communication links, and use of memories of various speeds and capacities. These problems will simply be magnified manyfold as the number of users, lengths and variety of links, and speeds and capacities of memories are increased to the extent necessary in regional and national networks.

National Policy

Southern Railway is developing its own internal communications net using microwave links for an information processing network adequate for its operational and management needs. This is said to be the largest privately owned microwave system outside the communications industry. Southern has acquired communications and computing equipment costing $30 million for this network.

Among other benefits, Southern Railway expects to need many fewer cars within its system simply because the computer network will give accurate and immediate information about the daily status of every car on its lines. Here is an important example of an information processing network within a single organization; others of comparable magnitude are in operation or being planned, perhaps only because it is not yet clear that there will be a national commercial information processing network able to meet the needs of these major users.

A consistent national policy is urgently needed to guide governmental agencies and private organizations in planning major information processing networks like that for the Southern Railway. Otherwise, this development will not likely be efficient and timely for the Nation as a whole. Many other major data transmission systems may be constructed and operated separately from the common communications system only because the Federal Government fails to induce timely action by the communications industry to develop and operate adequate data communication networks.

Standardization

The need for standardization of equipment and procedures presents immediate problems when independent networks are developed. Computer programs will certainly vary a great deal between independent networks, even when they have very similar functions; this variation in systems software will inevitably lead to incompatibilities when direct coupling between networks is attempted later. In any event, independent development of comparable software leads to waste simply because of the multiplicity of solutions to the same problem.

Standardization problems are familiar when complex systems must be developed, with the accompanying necessity for a very delicate balance between standardization and specialization. It seems very unlikely that governmental action will alter the present course of development of independent networks, if only for lack of understanding necessary for national solutions. Thus, actions are urgently needed to reduce waste from lack of standardization and unnecessary proliferation of independent networks.

The Federal Government could, for example, subsidize or perhaps even operate one or more major commercial information-processing networks. If this were done in the near future and in terms understandable to the many potential users of such networks, many otherwise undesirable independent network developments could be forestalled indirectly, even though our present technical knowledge is inadequate to permit expert planning of a major national commercial information processing network. However, the proposed action is justifiable in terms of gains in potentially invaluable experience with such systems at the national and regional levels.

Permanence, Privacy, and Sharing of Files

Another major problem, in part technical and in part legal and social, relates to ensuring permanence and privacy of data files within a commercial network serving many persons. It is especially important to assure privacy, for example, for the student, executive, scientist, and patient who may not want anyone to see their mistakes.

In current online, multiuser information processing network operations, information processors and associated memories are separated organizationally from the communication net. Typically, a user operating a teletypewriter remote from a computing center transmits and receives data over a standard commercial telephone or telegraph line. He has the usual assurance of privacy as a user of the commercial line, but must be protected against wiretapping. The computing center normally affords varying degrees of memory protection and privacy against entry to data files in the memories.

This form of system organization, in which communication links are operated by one organization and data manipulation by another, represents one possible approach to solving problems of permanence and privacy. However, this type of organization is fundamentally inefficient and therefore undesirable because it eliminates many gains otherwise possible through capacity sharing by several users.

Problems of memory protection, privacy of files, and interchangeability of capacity are difficult and familiar to every designer of advanced computing systems. Fortunately, a great deal of progress is being made toward their solution, at least for the relatively modest systems at Project MAC and the System Development Corp. It seems reasonable to expect that these important problems will be treated successfully for larger networks in future years. It may even become necessary to alter our concepts regarding privacy as otherwise highly desirable changes make old-fashioned privacy less and less attainable.

Protection of Rights of Users

The legal and social problems created by the emergence of commercial information processing networks are exemplified by problems of memory protection and privacy of files.

What recourse should a bank or depositor have if data pertaining to accounts are irretrievably lost because of negligence or to malfunction of memories within a commercial information processing network?

What is the degree and nature of responsibility of the owners of a network if the response to a physician's inquiry leads to an action by a hospital that is fatal to a patient?

Who is liable, and how is the extent of liability determined, if an industrial user of the network somehow manages to obtain data pertaining to the operations of an important competitor?

What is to be done if a regular user of the network somehow manages to change the programs controlling the network to produce a malfunction that goes unobserved for a considerable period of time and has damaging results to many users of the network?

What are the rights of users of a network with respect to orders by a court or governmental agency to enter memory files to obtain information possibly damaging to the user?

It would be quite easy to pose endless hypothetical questions of this kind, but these few illustrate the nature of this aspect of a broad problem.

These questions probably arise in some context unrelated to information processing networks. And while they are tremendously difficult in any case, the difficulties seem to be so greatly magnified in the context of commercial information processing networks that they become different in character rather than merely in degree.

Development of major commercial information processing networks may be delayed very greatly unless such problems are solved soon and the general public becomes convinced that the dangers will not outweigh the advantages. If such problems cause serious difficulties in the near future in present primitive networks, then confidence may be unnecessarily shaken simply because no action was taken to forestall them.

There certainly seems to be no possible immediate Government action that would entirely remove these difficulties. However, the Government could make it evident that it accepts some direct responsibility during the immediate future as reassurance to network developers and potential users. One modest step would be to license network operators and establish requirements regarding their technical and financial capability.

Protection of Public

A law enforcement example. Another kind of problem, more social and political than technical or economic, relates to the threats to the general public from new capabilities of information processing networks. For example, computers have already had some success in locating criminals and even in anticipating and preventing crimes. Recently a scofflaw was apprehended in New York City a few seconds after the vehicle's license number was transmitted to a central computer. An immediate check against the computer's memory and its response led to on-the-spot arrest and subsequent conviction of the driver.

At least in two counties in California a computer routinely compares the detailed record of a crime against information in its memory describing the habits and characteristics of all known past offenders, with frequent success in identifying those most apt to be guilty. Results of current research indicate that computers will soon be able to aid police officials to predict likely crimes which can then be prevented. Judges and probationary officials will also be able to interrogate files when considering rehabilitation actions to determine the best remedial treatment.

In a sense, these technological developments can be considered evolutionary advances in policing practices, just as was radar, fingerprinting, or the many other scientific aids for criminal investigation. Public resistance will certainly mount as law enforcement agencies catalog the lives of a large segment of the general population. For example, the New York City scofflaw attracted a great deal of sympathy from other motorists who felt that the computer technique was somehow unfair.

It is always important to prepare the public before introducing any new technological device or procedure that may appear threatening to older ways and customs. Sometimes innovations are impeded if not halted because advance preparations were inadequate. Care should be taken to assure that political and social pressures do not delay otherwise desirable advances.

A stenographic service example. Automation, and more recently automation based upon use of computers, has constituted a threat. It has often been attacked as socially and economically undesirable because the result sometimes seems to be increased unemployment, or at least temporary displacement of workers from their old jobs.

Commercial information processing networks will have desirable effects in the long run. There will be temporary undesirable effects, especially if governmental and private organizations do not act promptly to ameliorate the situation of those temporarily displaced or unemployed.

One commercial information processing network already specializes in the remote preparation of letters dictated into an ordinary telephone by a customer; we anticipate that this kind of service will develop rapidly as it becomes more feasible and economical. However, this new kind of stenographic system will have an impact in terms of possible unemployment and displacement of stenographers and secretaries. Thus, steps should be taken early to prepare stenographers and secretaries and others concerned with such a threat, so that corrective measures can be instituted.

The transition could be made gradually despite pressures to convert as rapidly as possible to the new and more economical system. However, broader social objectives must be considered, just as in other cases where technological advance creates temporary displacement of personnel.

Analysis of IPN Impact

Thus it is not only possible to control the transition, but such a transition can also be studied during its early stages to determine desirable controls. It is difficult to predict even the nature of the impact of stenographic functions performed within commercial information processing networks. It is still more difficult to describe the impact in quantitative terms. This development could be studied in its early stages to obtain quantitative information that would be helpful in devising effective controls for later stages. This type of management control study would need to be done on a regional or national scale, and probably by the Federal Government, for no private organization could afford the cost of such an undertaking nor would it be motivated to do so.

Therefore, the network can also be used to gather information about its own operations, automatically recording and storing detailed data, a capability which makes it quite special. However, this capability will not be available unless it is planned as part of the original system design, something again which would very likely require governmental action since private organizations would have no adequate incentive for the task.

Allocation of Scarce Resources

Another facet of the social and political question, and one of the very greatest importance, concerns where the emphasis should be placed, from the national viewpoint, in supporting the development of commercial information processing networks. Should the stenographic function be favored over making available biomedical information? Should the choice favor major potential users like the Southern Railway and other large industrial organizations, or should it lean toward meeting public needs such as law enforcement?

Should the necessary tremendous public expenditures be made for networks to serve the school system and libraries or to prime the development of the many kinds of networks that would improve the capabilities of private sectors of the economy?

Should public funds be devoted to developing information networks or to alternative methods for improving the same function? What, for example, are the relative merits of Federal aid in support of our present school system in contrast with the application of a substantial portion of these funds toward the development of an information processing network important in the future of the educational system?

Each choice has important social and economic consequences. Each question requires political action for its resolution. None of the questions has a ready answer, nor can they be answered easily even after extensive study. But it is vitally important that the range of questions be considered in their entirety.

No one Federal agency seems to be responsible for this type of broad national policy matter, with the task left to be done as it can through collaboration among many bureaus within Government. This traditional approach is not apt to lead to a good national plan in this instance because of the extent that the developing information processing networks impinge upon every area of human interest and human activity.

Motivation of Cooperative Endeavor

Another class of problems might be called motivational, with their treatment requiring technical developments, economic analyses, legal actions, and political adroitness. Generally, these problems require that methods be devised to encourage individuals and groups to make useful, creative, and unselfish contributions to the information network. They must be motivated in part by some system of explicit rewards and penalties, but primarily by a basic belief that the system can only develop through unselfish cooperation.

For example, the programs developed by GM as part of the DAC I system could be made available to competing firms if some way could be found to protect the proprietary interests of General Motors. Indeed, a competing company with similar design problems could, if it had a compatible computer, simply copy the computer programs, perhaps on magnetic tapes. At present, General Motors could certainly arrange to sell or rent such programs to others, as is often done by other companies. There is some doubt that the patent or copyright system affords adequate protection for programs interchanged in this manner, but presumably this could be corrected through suitable legislative action.

The character of similar proprietary problems for large information networks is changed, even though the change may seem only to be one of degree. Almost all such programs are continually revised and improved both by the originator and by other users, and so the development of shared programs automatically becomes cooperative. Thus it would be exceedingly difficult to measure the contribution of each user. But because cooperative developments are socially and economically desirable, it is important to devise methods that will motivate users of the system to contribute to aid the advancement of the art for the joint good of all.

Patent and copyright systems, our system of contracts and agreements, and many social and ethical customs that help produce cooperation provide parallels for the problem. The difference in information networks arises from the immediacy of transferring new information from the originator to other potential users as a prime characteristic of the network operating reliably at electronic speeds. To encourage full cooperation, one or more information networks may have to be operated either by governmental agencies or as regulated monopolistic utilities.

One disadvantage in operating an information network as a public utility is that individuals and groups could offer improvements only after negotiating with the utility about the terms of payment. Companies operating telephone systems have the same problem in purchasing component parts for their systems, since many suppliers offer competitive items and on financial terms that must be negotiated. Presumably, the same methods could be used in acquiring physical components for an information network operated as a public utility. However, there seem to be no satisfactory methods for conducting negotiations on software components since this kind of innovation has usually been protected by secrecy, a method that usually seems to fail to protect the originator of software contributions to information networks. It is frequently possible to give full access to certain computer operations while preventing all users from having the code itself, and in this case secrecy does work.

Competition

A closely related, troublesome problem exists whether the information network is operated as a commercial enterprise by a private organization or is controlled in some way by the Government: A desirable innovation may be unwisely rejected by the network's management. When many organizations offer competitive products and services competition usually helps assure that desirable innovations find their way into the operating systems, an important virtue of our free enterprise system.

Perhaps, then, there should be several major information processing networks to guarantee healthy competition to encourage technological advances. Several competing information networks could be organized geographically with appropriate interconnections, and be allowed a good deal of independence in developing innovations. Competing software producers, data transmission system operators, and network operators could, of course, be established on bases other than geographical to prevent monopolistic control.

For example, the American Express Co. competes with the Federal postal service. We cannot evaluate the past effect of competitive operations in this case nor judge whether such competition would be desirable in the case of information networks, but the possibility seems worth considering.

Quite apart from any possible competitive advantages between publicly and privately operated networks, it may be desirable to create at least one public network in the immediate future to accelerate information network development and provide experience and methods for subsidizing future network operations. Many possible prototypes could be considered in this context in terms of past experiences in the field of transportation, particularly since the impact of information networks may eventually be as great as that of transportation systems in the past. Indeed, there is some evidence that greatly improved communication and information transfer systems may change both our urban patterns and transportation needs over a period of the next decade or so.

General Governmental Actions

Accelerate desirable growth. The final major problem we shall discuss concerns governmental organizations and actions, primarily at the Federal level, and the task of accelerating the development of major commercial information processing networks found to be desirable through proposed benefit-cost studies.

The question remains as to preferred organizational and operational actions by the Federal Government that would bring about the desired result.

Extend previous support. Historically, advances in information processing technology have resulted almost entirely from financial support from

the Federal Government, at least in the pioneering stages of each major advance. Army Ordnance Department research support led to the ENIAC, usually considered to be the first of the modern stored-program electronic computers. There are many examples of critical Federal support for computer development since World War II, and more recently the entire effort has been greatly assisted by projects under the space program.

Although the concept of online time-sharing multiuser computing systems was not new, the great recent advance in this direction seems certainly to be due to the substantial financial support given by the Advanced Research Projects Agency of the Department of Defense to Project MAC at MIT, to the System Development Corp., and to various other research groups. Earlier work at the MIT Lincoln Laboratories, the Rand Corp., and other places also progressed because of Federal support, especially from the Department of Defense.

Federally supported development of the SAGE air defense system, and more recently at the General Electric Co. of online computers designed for command-control purposes have yielded processors and memories that are finally reasonably efficient for time-sharing computer systems. Without these boosts by the Federal Government recent advances in computer technology would have been unlikely; it also seems reasonable to suppose that Federal support will continue to be essential for further major advances in information processing systems technology.

Develop overall planning. There is much to be said for competing agencies to stimulate innovation, and it is far from evident that overall planning would have led to better computer developments. However, an overall guiding plan produced at the top level of the Federal Government might improve the selection of future programs even by the same agencies. A start has been made through recent planning activities of the President's Office of Science and Technology and through the Federal Council and other interagency coordinating committees which may well be the bests steps for the present. There is certainly no great difference between the planning problems of advancing information processing system technology and those in many other fields where technological advance is rapid, and it seems reasonable to depend upon comparable organizational and management mechanisms in all such cases.

Special Governmental Actions

COSATI library planning. An interesting current example of planning under the Office of Science and Technology can be found in the work of the Committee on Science and Technology Information (COSATI), a subcommittee of the Federal Council. It is presently concerned with formulating policies to guide the development of national biomedical networks and national library systems for information processing networks to store and retrieve books, journals, documents, and other graphic material. Certainly COSATI should be able to produce a technically feasible, economically desirable, socially acceptable, and politically workable proposal for the organization and operation of information processing networks.

If the Federal Government does act to implement recommendations made by COSATI, it will be important that all Federal agencies, and indeed many other governmental agencies and private organizations, cooperate in developing portions of this national information system. Many information subsystems exist as part of a system that now performs this same information function, though not at all adequately. Thus a great deal can be learned by comparing the effectiveness of the older system with the new national system as it develops.

A decision to proceed with such a national information network would constitute a giant step forward toward the solution of most of the problems discussed here. However, this particular type of information network would not necessarily be the best one to develop at the present, even to find solutions to the major problems discussed, for it seeks to fill a great void whereas other network possibilities might supplant existing systems that are operating satisfactorily but less efficiently.

A federally supported major IPN. It would seem desirable that the kind of thorough study being made for COSATI would be followed in connection with every major proposal for national or federally supported networks.

Any particular information processing network most worthy of support by the Federal Government at this time should be selected on the basis of careful study. The most urgent need is to proceed with at least one major information network as the quickest and surest way of gaining badly needed experience. Such a major action by the Federal Government will undoubtedly also provide badly needed encouragement to many segments of industry.

4. Conclusions and Recommendations

The following conclusions and recommendations are supported only by the discussion of prospects and problems in this report. They are not defended quantitatively in detail, nor do they represent the results of extensive analyses. Our findings are based upon facts and opinions published elsewhere or obtained by personal correspondence and conversation with many experts in various aspects of this broad field.

This report, and therefore its conclusions and recommendations, is biased in the direction that technological problems are easily solved, that computers are of great importance for our future, and that information processing networks serving many users constitute the next great advance in the application of the computer art to practical affairs. The problem, then, is stated as that of finding actions that might best be taken by the Federal Government, both by the Congress and the Executive Office, to encourage and accelerate desirable developments of information processing networks.

Commercial information processing networks will not develop as rapidly as desirable unless prompt steps are taken to increase greatly the capacity and efficiency of data storage, switching, and transmission facilities. The demand for this increase will not be apparent unless and until there is reasonable certainty that such facilities will be available on an economical basis; otherwise information network system planners and developers cannot afford to consider substantial expansion.

Ideal efficient data communication facilities differ in character from familiar two-way message transmission systems. An ideal local data switching center with direct two-way lines to its customers would typically store tagged bursts of data from several customers before forwarding them to centers elsewhere. This store, process, and forward operation would take place in comparable manner at all centers. Service charges, which would depend upon the extent of use, would be made according to pricing schemes based upon marginal cost analysis.

Information systems technology is not yet sufficiently advanced to support the development of ideal regional and industrial networks, but several multiprocessor, multiuser online computing systems now under development or in use are providing experience that should gradually enable us to approximate this ideal.

[illegible]either the structure nor the history of the com-[illegible]tions industry makes us optimistic for the ra[illegible]lopment of a data communications netwo[illegible]ble of meeting the needs of commercial [illegible]fo[illegible]tion processing networks during the coming [illegible]. Governmental action is needed soon to [illegible]h an auxiliary data communications n[illegible]y offering sufficient inducements [illegible] privat[illegible]try or by creating a new Federal [illegible]ing agency in order not to lose the great p[illegible]ntial gains possible from more rapid development of information processing networks.

Developments in data storage and processing equipment, input and output devices, computer programs and programing languages, and complex information processing systems, together with many other hardware and software advances, promise advances in an already abundant technology in support of future commercial information processing networks. However, these capabilities are countered by a comparable inability to select and design information systems of greatest importance for the future of our society.

During the past 25 years substantial advances have been made in developing and applying the analytical approach to complex system design and planning problems, especially during the past few years with respect to defense systems. It has recently become fashionable to use the results of benefit-cost studies in designing and planning many kinds of complex systems other than those for defense purposes. The Office of the President has urged the use of benefit-cost studies generally throughout the Federal Government, and such studies of information network possibilities are being made currently for the Office of Science and Technology. These may soon yield useful guidance from the Federal Government for all concerned with advancing the development of commercial information processing networks.

Technological advance, which has resulted in good part from Federal support, is now so fast that it may no longer be desirable to depend upon more or less fortuitous events, such as emergency war needs for bombers and transport aircraft, to encourage major new technologies. It may well be preferable for the Federal Government to support one application of information system technology, say the proposed national network of libraries and information centers, to afford maximum assistance and encouragement for other important applications of this technology.

Commercial information processing networks can develop effectively only if users are motivated to contribute cooperatively innovations in procedures and data stores. Suitable methods must be devised to guarantee users privacy and protection against loss or alteration of their files, and to find workable procedures for making restitution in case of failure of these methods. (Here the difficulty lies in not being able usually to determine the cause of failure.)

Methods must be found to reward those who contribute improvements to the system. Copyright and patent processes seem totally inadequate for protecting contributors, and secrecy seems impossible by the very nature of an information system. In many cases, an improvement may be made almost continuously over a considerable period of time; for example, the continual revision of a course of instruction offered to the users of the network. Thus, determining a proper basis for rewards is difficult or impossible. Perhaps best would be to start by simply urging unselfish innovative cooperation for the joint benefit of all users, and then install reward procedures as feasible.

Most important is the need to capture general public interest and instill confidence in the potentialities for future benefits of information processing networks. These needs range from offering assurance to those whose job security is threatened, to convincing every teacher and student that the information network should be developed and used because it is beneficial. Systematic records regarding its own use kept by the network would include data useful in monitoring and controlling the reaction to the system of its users, especially important for earliest systems to provide experience in forestalling undesirable reactions later.

Fortunately every telephone and teletypewriter can be used as a terminal for nearly every information processing network. The general public should be enabled and encouraged to get direct experience in the use of these networks as soon as possible. Most schools could and should have at least one teletypewriter installed to enable teachers and students to understand and demand information processing services and become key participants in the design and improvement of the information processing network. For effective participation, the system must include programed responses to user inquiries to enable users to learn and relearn continually as the system changes.

Legislation and regulation at national and local levels will have to be changed if information networks are to be developed rapidly and successfully. Present laws, regulations, and customs affecting the communications industry lead to actions and delays that are unfavorable for the development of an adequate data communications network. The responsibility of commercial information processing network operators to the using public may well lead to legal requirements for licensing and other steps to ensure technical and financial capability of the operators. Many, even most, of these problems have direct counterparts in other fields; some seem novel because of the extent that users of the system also help to improve it.

We have assumed that commercial information processing networks will inevitably be developed and certainly be beneficial. Such networks could contribute to meeting recognized unmet national needs or social goals. For example, information processing networks might alter present patterns of urban development.

We believe that future uses of very advanced information processing networks will compete with and often supplant our present modes of interaction, and thus greatly increase our dependence upon the communication network. This will be accompanied by a reduction in the use of our transportation system. For the next few years, any such significant changes should be taken into account in future planning.

It is recommended that:

(1) Full responsibility, adequate authority, and necessary funds be given to an appropriate agency of the Federal Government, either existing or created for the purpose, to ensure that the Nation's communication system is planned, developed, and operated to provide efficient and adequate capability to meet future needs for information (data) storage, processing, and transmission.

(2) The Federal Government bring into being, as rapidly as technology permits, at least one limited but major information processing network that is planned, developed, and operated to:

- (a) Accelerate technological advance and gain experience in appraising economic and social benefits and costs of information networks; and
- (b) Help meet a recognized unmet national need, such as for better information transfer through a national network of libraries and specialized information centers.

(3) Authority be granted and funds appropriated as necessary to enable appropriate agencies of the Federal Government to create and support immediately one or more commercial information processing networks to serve the general public over the regular telephone and telegraph network, at an approximate annual expenditure of about $10 million per center.

(4) The Federal Government review its own future needs for computers and information processing services to determine which needs can best be met by information processing networks, whether operated internally by the Government or externally by private organizations.

MANPOWER IMPLICATIONS OF PROCESS CONTROL COMPUTERS IN THE PROCESS INDUSTRIES

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ABSTRACT

Process control by digital computers is the latest step in the evolution of control techniques. It includes simple recipes for running early batch processes, measuring devices and controllers for regulating individual process conditions, and data loggers for collecting and typing process data in an orderly form. Use of digital computers for process control began about 1958–59 and has grown rapidly, about 300 systems having been installed or ordered in the United States at the end of 1964.

The cost of a process control computer installation is $200,000 to $400,000, sometimes more, divided about equally between equipment and services. Each installation requires several man-years of effort by technical personnel for planning, design, programing, and installation. Investments of this magnitude have been justified primarily by increased production, decreased waste, better control of quality, greater safety for personnel, and reduced chance of damage to equipment.

Process managements did not expect and have not experienced reductions in operating manpower requirements, chiefly because the number of operators was already at the minimum practical level. A survey of 22 user companies, accounting for about one-fourth of the process computers installed or ordered in the United States, showed many instances of no reduction and an average of about one operating employee per computer.

Manpower reductions caused by process computers per se are a negligible part of employment changes observed in recent years in the petroleum, chemical, iron and steel, electric power, pulp and paper, and cement industries which now account for 90 percent of the process computers installed or ordered. More significant factors are the introduction of new processes and the use of larger processing units.

It is estimated that these six industries might eventually install as many as 2,800 process computers; assuming 4 employees displaced by each computer, their ultimate displacement would then be 12,000 employees. With an allowance for other industries, the maximum effect would be 12,000 to 20,000 employees displaced.

These estimates do not include technical personnel who must be added for process computer system planning, design, programing, and installation. A shortage of these people and an insistence on benefit-cost calculations for each proposed installation are the primary factors in setting the rate at which process control computers are being installed.

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Manpower Implications of Process Control Computers in the Process Industries

1. Fundamentals of Process Control

Before discussing the manpower implications of control computers in the process industries, it seems appropriate to offer a brief technical description of the activities under consideration. In this section, a few basic terms are defined as an aid to understanding and as a means of bounding the field to be explored. The evolution and objectives of process control technology are described briefly to explain the current interest in computers as control devices. In the next section, process computer systems are discussed in greater detail to indicate their functions, installation procedures, justification, and importance.

A. Definitions

For purposes of this report, a process can be defined as an assembly of equipment performing physical and chemical transformations on raw materials in order to convert them into more useful or valuable products. The physical transformations include such operations as crushing, grinding, distillation, filtration, melting, and freezing, while chemical transformations include the combination and disassociation of materials by reactions often conducted at high temperatures and in the presence of catalysts. Processes for the manufacture of gasoline, chemicals, steel, paper, glass, synthetic rubber, and many other materials easily fit this definition. With only a slight stretch of the imagination, it can also be applied to the generation of electricity from coal, oil, gas, or atomic fuels. It could even be stretched to include the transport of gas or oil by pipelines, where the product gains value by being moved close to points of consumption.

As a further description of the area of technology considered in this report, we will not deal with manufacturing processes found, for example, in the fabrication of consumer products such as automobiles, refrigerators, or cameras. Nor will we consider the many miscellaneous applications of control devices, computers, or digital equipment to such diverse jobs as machine tool control, engine testing, missile checkout, television switching or toll registration.

The term "process control" refers to procedures and devices which can be employed to cause a process to perform in a desired manner. The nature of these procedures and devices, their functions and objectives are explained more fully later in this report.

As the name suggests, an *analog computer* employs some set of physical elements which is "analogous" in its behavior to another physical system. In the first analog computers, known as mechanical differential analyzers, the positions of rotating shafts represented the variables of the system under consideration; mathematical operations of addition, multiplication, and so on were performed by such devices as gears and mechanical differentials, and the results were read on dials attached to the rotating shafts. In more modern analog computers, electric circuit elements and amplifiers are used; the results are read from indicating meters or recorders. With either type of analog computer, elementary building blocks are combined to form a model satisfying the same mathematical relationships, in a form more convenient for manipulation and measurements, as the original system to be studied.

In a *digital computer*, on the other hand, the basic mathematical operations of addition, subtraction, multiplication, and division are performed by counting rather than measurement. Operations are carried out on a discrete set of marks or numbers. Some digital computers have been constructed to employ the customary decimal system in which the marks or numbers are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. However, most digital computers now use a binary system in which the only marks or numbers are 0 and 1. Whereas the decimal system is based on powers of 10 (1, 10, 100, 1000, . . .), the binary system is based on powers of 2 (1, 2, 4, 8, 16, 32, . . .). The binary system has the great advantage that operations can be mechanized with devices having only two states: Switches which are open or closed, circuits which are conducting or not conducting electric currents, magnetic elements which are magnetized or not, and paper tapes or cards which are punched or not at particular locations.

Besides performing arithmetic operations, a digital computer is provided with a memory for storing data, as well as means for taking numbers from memory and returning them to memory, for receiving data from external sources and making its results available in return, and for governing its future actions by examining the result of a calculation to see whether it is positive or negative. Solution of a problem with a digital computer involves the same steps needed with a common desk calculator: Reading data from some basic source, putting the numbers into the machine, initiating an arithmetic operation, either recording the result or putting in additional numbers and executing further arithmetic operations, and possibly repeating the whole sequence with new data. By following a set of instructions or a program prepared by a programer and stored in its memory, a digital computer carries out a similar sequence of operations, automatically and very rapidly.

An analog computer is assembled from basic building blocks to fit the problem being solved; its cost is, therefore, somewhat proportional to the complexity of the problem. With a digital computer, on the other hand, a minimum complement of equipment is needed regardless of the problem complexity, with only modest additional amounts of equipment necessary for more elaborate tasks; its cost is, therefore, somewhat independent of the problem. (Major increases in computational requirements will force the use of considerably bigger, faster, and more expensive digital computers, however.) Also, the accuracy of solutions obtained from analog computers tends to decrease as more building blocks are connected together.

For economic and accuracy reasons, analog computers are employed for relatively small problems. A substantial number of analog computers have been installed for process control. Because of the relatively modest scope and cost of individual installations, however, they consume little engineering effort, receive little publicity in the trade or public press, and have little or no effect on employment.

Digital computers have advantages in calculating capacity and other characteristics, such as accuracy and flexibility, which recommend them for more elaborate process control applications. The increased scope and the cost of these projects (for equipment and associated services) cause them to receive greater attention from management and engineering personnel of the user organizations; the potential effects on employment are correspondingly greater; and the number installed is comparatively small (but growing). When anybody calls attention to the possible social implications of "computers" or "electronic brains," the reference is nearly always to digital computers. For these various reasons, *this report concentrates on the process control applications of digital computers.*

Different industries use different terms to identify the men responsible for the direct, minute-by-minute operation of their processes. For example, the paper industry speaks of "machine tenders"; the steel industry of "melters" and "rollers"; the power industry of "board men" and "outside men"; the chemical and petroleum industry of "board men" and "still men"; and so on. In this report, they will all be referred to simply as "operators."

In general, operators do not have college educations, and many are not high school graduates; they are normally paid on an hourly basis. Their duties are distinct from those of the technical and general managers of the plant or parent organization, who set goals and give instructions to the operators as well as performing other functions. The operators in a process plant, who are also distinct from maintenance men and so-called common laborers, work at about the same level of decision-making as the process control computer. From an employment standpoint, then, it is the operators who may be most affected by installation of process control computers.

Individual operators work about 40 hours per week. Process plants, however, usually run around the clock, 7 days per week. Since there are (24) (7) = 168 hours in a week, it takes 168/40 = 4.2 or somewhat over four operators to man each shift position, the exact number depending on the pattern of shift rotation and the amount of overtime worked. Thus elimination of one shift position, where this step is possible (for any reason), means displacement of roughly four employees who must be moved to another job, retired, or discharged.

B. Evolution of Control Techniques

For centuries, manufacture of metals, dyes, wine, cosmetics, and such basic materials as salt, lime, alum, and asphalt has been conducted in batch processes. These early batch processes follow much the same pattern that a housewife follows in making a loaf of bread. The steps include weighing ingredients; subjecting them to some physical operation, such as grinding, crushing, or mixing; heating them in a pot or an oven; and perhaps offering a prayer or muttering some magic phrases to make everything come out right. The process steps were developed by experiment, and control procedures consisted of careful adherence to recipe. Constant attention was required to make these batch processes run smoothly and to avoid waste.

Some products—such as pigments, dyes, and drugs which are made only in relatively small quantities—are still manufactured using batch processes. Even some major products—such as steel, woodpulp, and tetraethyl lead—are made largely by batch methods. However, most products of the process industries are now made in continuous processes.

In a continuous process, materials are carried from step to step by pipes or conveyors. Related conceptually to the modern assembly line, the continuous process offers obvious benefits in productivity and it has had important consequences for process control.

In principle, at least, the advent of continuous processes simplified the operator's task. Temperatures, flows, pressures, and other variables were to be maintained at more or less constant values. An operator could read a gauge, mentally determine if the gauge reading was too high or too low, turn a valve in the proper direction to correct any departure from the prescribed reading, and turn his back on the process for a short time. Only intermittent attention was needed to readjust process conditions after upsets caused by changes in raw material characteristics, equipment breakdowns, or other unpredictable events.

The automatic controller was invented partly to relieve the operators of the need to stay close to their gauges and partly to provide better process control.

This device embodied means for measuring the condition to be controlled, comparing the measured value with a desired value, and automatically taking action to bring the two values into agreement. An early example was the steam engine governor. Controllers were soon used to regulate a wide variety of process conditions: Flow, pressure, temperature, level, and speed, to name just a few.

A typical automatic control system is shown in figure 1. In this system, a process fluid is heated by passing through a pipe (or pipes) around which steam is made to flow. At the outlet of the heat exchanger, a measuring device senses the actual temperature of the process fluid. In the controller, a signal corresponding to the measured temperature is compared with a desired value which has been inserted by an operator. If the measured value is less than the desired value, a signal goes to the valve causing it to open wider, increasing the flow of steam to the heat exchanger, and raising the temperature of the process fluid. If the measured temperature is greater than the desired value, the controller acts to close the valve, reducing the steam flow, and lowering the temperature of the process fluid. The system shown in figure 1 performs the same function as a household thermostat.

The introduction of automatic controllers, starting about 40 years ago, permitted substantial reductions in operating manpower. It has also caused a major change in the duties of a process operator. Now he does not have to reposition valves continually to counteract disturbances to the process. He is still expected to look out for actual and imminent failures of process equipment and instruments, keep a "log" or record of operations, and generally watch over the performance of the process. Together with process engineers, he has to decide what temperatures, pressures, flows, levels, and so on should be maintained at various points in the process. From an actual participant in the production process, the operator has become a supervisor.

By substituting different types of measuring devices, the technique illustrated in figure 1 can be used to regulate a wide variety of process variables. In recent years, great effort has been exerted to develop analysis instruments which measure material qualities, such as chemical composition, water or moisture content, thickness, hardness, opacity, color, viscosity, density, and octane number. Instead of measuring the environment in which a product is made, these instruments sense characteristics of direct significance to the consumer. At the same time, they allow control to closer tolerances on these characteristics and thus production of higher quality products.

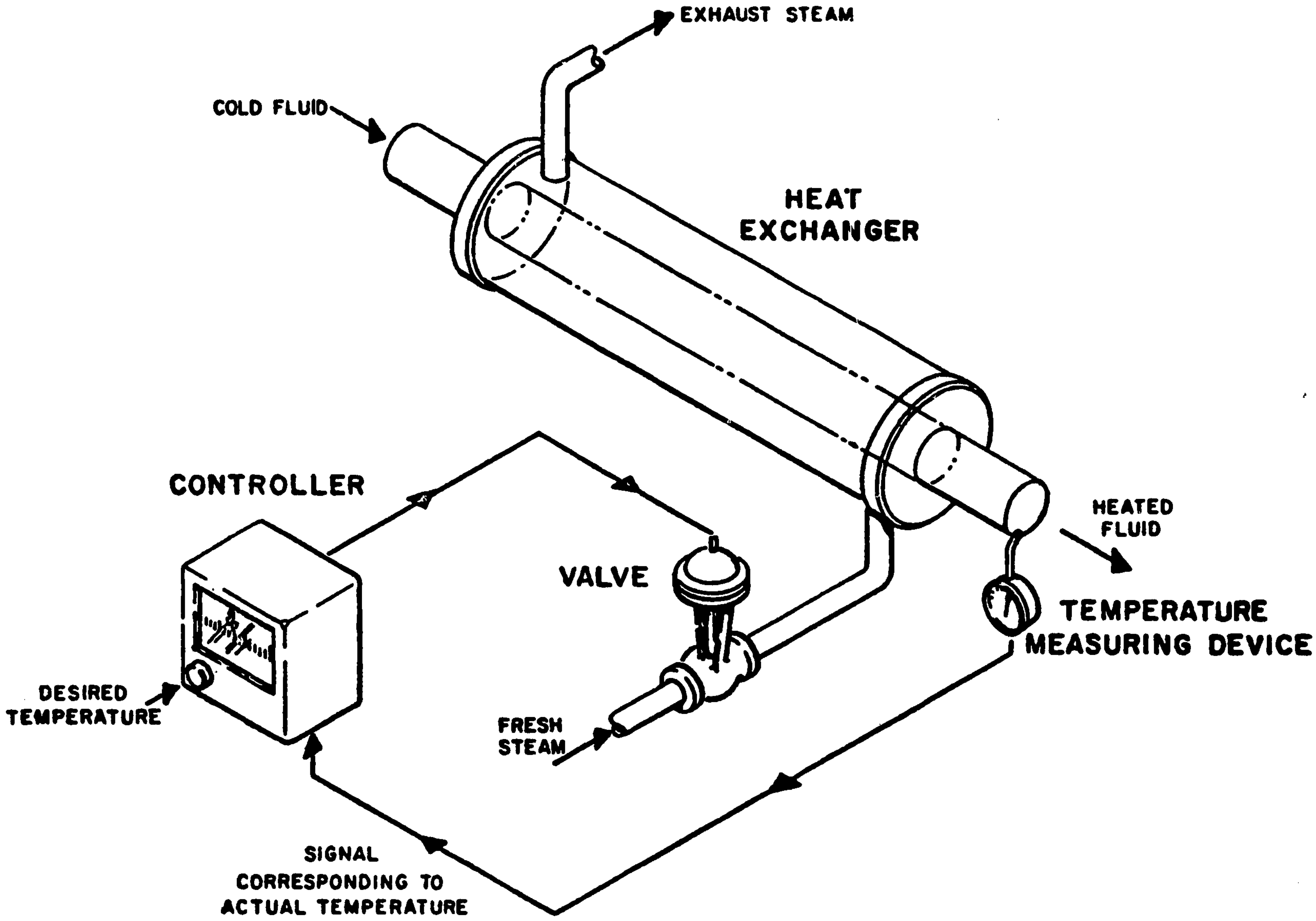
Use of analysis instruments for process control may have some effect on employment. In some situations these instruments provide information automatically which otherwise would be obtained by laboratory tests conducted by technicians or, sometimes, by the process operators themselves. While introduction of these instruments could permit a reduction in personnel, usually it means only sensing process conditions more often, with greater accuracy, and with less delay.

As a supplement to conventional measuring and control devices, the automatic data logger was proposed about 10 or 15 years ago. Data loggers were connected to process instruments and operated electric typewriters to produce a permanent record of process conditions. The equipment could perform some rudimentary calculations, such as multiplying incoming signals by a constant to give outputs in proper units, e.g., degrees Fahrenheit or gallons per minute. It could also provide daily totals for raw material consumption or production.

Data loggers cost perhaps $50,000 to $100,000 or more, depending on the number of variables involved. Justifications for such expenditures were supposed to be found in better data for both accounting and engineering use; elimination of some standard recorders; and reduction in clerical labor needed to get routine accounting data from process records. In general, benefits proved less than adequate to justify the investments, and data loggers never became popular. Their functions are now performed in a growing number of plants by digital computers.

Like the nuclear reactor, the transistor, and the jet airplane, the digital computer is a recent invention. While some of the basic concepts are

FIGURE 1.—*Typical Automatic Control Loop*



quite old, practical means for their realization appeared only during and after World War II. Developed originally for engineering and scientific calculations, and shortly thereafter adapted to accounting and business functions, digital computers are now being applied in manufacturing plants. Superimposed on conventional equipment and procedures, control computers further modify the job of the process operator.

Internally, a digital process control computer is much like the computers used for scientific and business calculations. In addition, it is equipped with means for connecting it to process instruments and control devices. As a result, it can (1) accept input signals corresponding to process conditions; (2) perform arithmetic computations (addition, subtraction, multiplication, division, etc.); (3) make comparisons ("is A larger than B?") and decisions; and (4) develop output signals for control and communication purposes.

A process control computer usually has a variety of assignments. Its most important job is to determine and enforce the best conditions for process operation. In some chemical processes, for example, it is known that the best temperature at any particular time depends on the flow rate and composition of a feed material, the condition of a catalyst, the maximum tolerable amount of impurity in the product, and other factors. By means of equations built into the computer by the system designers, the best temperature can be computed and transmitted to a temperature controller, which then has the job of regulating the process at the desired temperature.

Because it continuously receives information from process instruments, the computer can generate a printed log. This record can include not only raw instrument readings, but also computed yields and efficiencies for process engineers or average and total flows for the accounting department. Thus, the control computer serves part of the time as a data logger.

A control computer can be programed to carry out the complex sequence of operations needed to start up or shut down a large plant. The sequence used may be planned in advance or it may depend on measurements received from the process. In addition, the computer can check instrument readings for indications of trouble in the process by comparing the incoming signals against high and low limits.

The sort of process computer application just described is known as *supervisory control;* the computer assumes some of the supervisory functions of the operator. In case of a computer failure or other emergency, the operator can resume his original role.

With a sufficiently reliable digital computer, the controllers can be eliminated and the computer connected directly to the valves at the various locations in the process. As in other computer control systems, the computer receives measurements of process temperatures, flows, pressures, and other variables. Now, however, the computer checks each variable in turn, compares the present value with the desired value, and sends out signals to open or close the appropriate valve. This mode of control has been called direct digital control (DDC), because a digital device is connected directly to the valves controlling process conditions. A relatively recent development, direct digital control will affect process control technology but should not have any effect on operator employment since it only substitutes one form of control equipment for another.

Most of the currently installed process control computers are concerned with a single unit, that is, with just a part of a complete manufacturing plant. Examples would be a rolling mill or a blast furnace in a steel mill, a fluid catalytic cracking unit in a petroleum refinery, a pair of kilns in a cement plant, a pulp digester in a paper mill, or a polymerization line in a synthetic rubber plant. In the future, more emphasis will be given to computer applications for plant-wide control. These future installations, employing several interconnected small computers or a single large computer, will concern themselves with the relationships between units and will perform control functions within individual units. This concept has been dubbed multiunit control, and the first systems of this kind are now being installed.

C. Objectives of Process Control

Process owners and operators have a number of objectives. Since a process is generally run to return a profit to its owners, an operator's first objective may be to maximize earnings from equipment under his supervision. However, he must also consider a number of secondary, but nevertheless important, related objectives:

(1) Meet production schedules and have products ready for shipment at the desired time;

(2) Keep product qualities within specifications;

(3) Minimize waste of fuel, water, electricity, steam, catalysts, solvents, and so on;

(4) Avoid conditions leading to equipment breakdowns, lost operating time, and unexpected or unnecessary maintenance costs;

(5) Protect personnel from injury and equipment from destruction due to explosions or other catastrophes.

These objectives may be difficult to satisfy simultaneously. An operator may detect that one product quality is outside its specification and correct the situation, only to find that his correction has caused another product quality to become unacceptable; a number of corrections may be necessary to bring all of the product characteristics within the prescribed limits.

In some cases, these objectives may even be contradictory. Efforts to boost production rates, for example, may entail overloads of pumps and compressors (with increased maintenance costs), less efficient removal of impurities (with a degradation of product quality), or operations with more hazardous combinations of materials (with an increased risk of explosion). Improvements in quality may mean higher costs for removing contaminants or greater amounts of raw material. At very high production rates, yields may decline so that excessive amounts of raw materials are required; operation at the high rates may then be uneconomic, even though necessary to meet a customer commitment.

By combining financial and technical considerations, process supervisors could determine a combination of process conditions providing the best compromise between the numerous objectives. The real need, unfortunately, is not a page describing a single set of process conditions but a whole book or library of books containing pages applicable to the many situations encountered in any process plant. This need arises from changes affecting the process:

(1) Customers increase or decrease their orders, or ask for better or different products;

(2) Prices for raw materials and products change from time to time;

(3) Chemical and physical characteristics of raw materials vary;

(4) The quantity of raw material available for processing increases or decreases;

(5) Performance characteristics of process equipment change as catalysts lose their activity, heat exchanger surfaces become fouled, bearings wear, and so on;

(6) New equipment is added to expand or improve the process;

(7) Equipment breaks down unexpectedly and through no fault of the operators;

(8) Weather conditions (such as air temperature, humidity, and wind velocity) vary continuously and may have significant effects on process performance.

Without changes or disturbances of these kinds, no process control devices or procedures would be needed. In continuous processes, valves could be locked in place at positions leading to manufacture of the required products in the desired quantities. In batch processes, cam-actuated valves (which pay no attention to the progress of the operation) could be used to enforce preplanned variations of process conditions. Because changes do occur, this approach is impractical.

Control equipment—measuring devices, conventional automatic controllers, and control computers—is a means for realizing process objectives in the face of these unavoidable disturbances. At the present time, it is not viewed as a method for making significant changes in operating manpower. When a new plant is designed, control equipment is installed as a matter of course. Arguments arise about the need for particular instruments or control functions, but these arguments are settled on technical or cost grounds, not on employment considerations.

2. Digital Computers in Process Control

Expanding upon the descriptive material presented in section 1, of this section offers a more detailed discussion of the computer equipment used for process control, its functions, installation procedures, justification, and present importance.

A. Equipment

Computers for process control can do all of the operations carried out by similar machines used for business or scientific data processing. These operations include addition, subtraction, multiplication, division, storing a number in memory, reading a number from memory, interpreting and storing data from a punched card or tape, actuating a typewriter, and so on. In addition, they have a number of special features:

(1) Means for direct connection to sensing devices such as thermometers, composition analyzers, and flowmeters;

(2) Means for connection to control devices for adjusting process conditions;

(3) Means for interrupting one function in order to carry out a more important program, returning to the previous program when the higher priority program is completed;

(4) Equipment and programing techniques to insure a highly reliable system and a safe response to any malfunction that should occur.

In contrast with the conventional controller, a digital computer used as a process controller is able to compare two numbers ("is flow rate A greater than flow rate B?" or "is Pump 5 loaded beyond its capacity?") to make decisions ("since the pump is overloaded, it is necessary to open Valve 107"); to take simultaneous control actions at many points in the process with due consideration of their effects on each other; and to produce detailed records of the incoming data, results of intermediate calculations, and its control actions.

A schematic diagram of a process control computer system is shown in figure 2. Process sensing devices are connected to the computer through converters which change the original signals into a form acceptable to the computer.

Most process instruments provide continuous signals in the form of an electrical voltage or an air pressure which is proportional to the quantity, such as temperature or flow, being measured. These signals must first be changed to a common electrical form, using suitable amplifiers or pneumatic-to-electric converters. They are then sent, one after another, to another device which changes them to digital form and routes them to assigned places in the computer memory.

Some instruments supply signals already in digital form. These signals, with others from the operator's input devices, can go directly to their places in the computer memory. The computer program itself is inserted in this manner.

After executing its various programs, the computer has generated information in digital form for control, display, recording, and alarm purposes. Some of this information can be sent (almost directly but with provisions for meeting the speed limitations of auxiliary equipment) to typewriters, alarm annunciators, digital displays, tape punches, etc.

When computer outputs are used for control purposes, they must generally be converted from a digital form into a continuous electrical signal. Often conversion of this type of signal into a corresponding air pressure is also required to operate pneumatic equipment.

A control computer communicates with process operators in two ways: To receive data, instructions, and programs for guiding its actions, and to send out information that may be useful to the operators. Three main methods are used for letting the operators communicate with a control computer:

(1) Mechanical or optical devices for reading perforations in paper tape or cards (used to get the original program and later changes or corrections into the computer memory);

(2) Push buttons and switches whose position can be detected by the computer (used to specify some special action by the computer):

(3) Dials and keyboards for putting numerical data into the computer (used, for example, to insert results of laboratory tests which serve as a substitute for directly connected instrument readings).

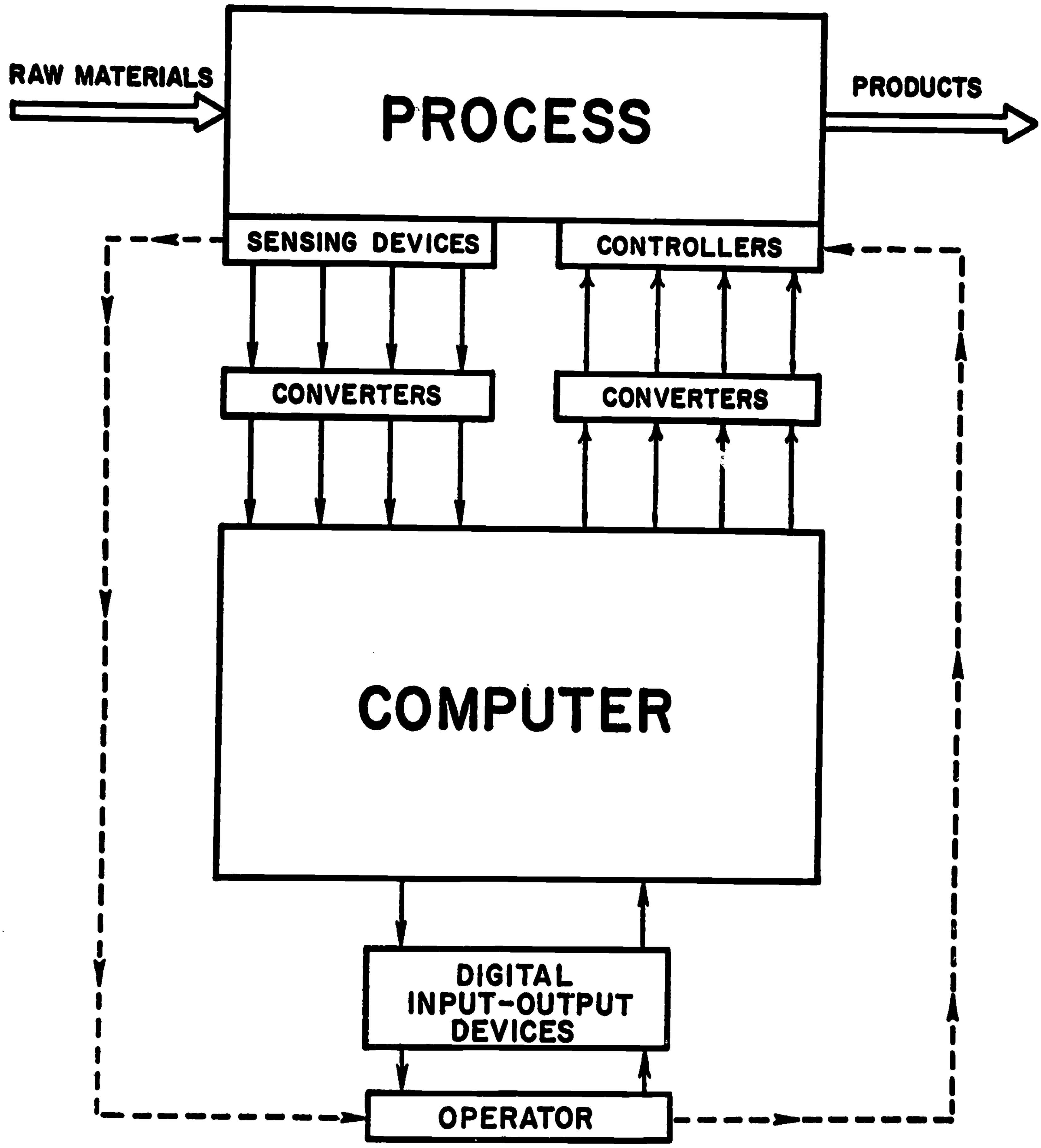
Many techniques are used to allow the computer to inform process operators of its actions and to record data for future use:

(1) Automatic typewriters (used for special messages and also for routine summaries of process data, either periodically or on demand);

(2) Lights, buzzers, bells, and other on-off devices (used as alarm indicators to announce emergency conditions);

(3) Arrays of indicators for display of decimal quantities and other symbols (used to show current

FIGURE 2. *Schematic Diagram of Computer Control System*



values of a variable, or several in sequence, with appropriate identification);

(4) Electrical meters which show, by the position of a pointer along a scale, the present value of a variable (used to give a continuous indication of the value);

(5) Recorders, generally employing one or more pens writing on a strip or circular piece of paper (used to give a permanent and continuous record of process variables for visual inspection);

(6) Devices to prepare punched cards, punched paper tape, or magnetic tape (used to feed data into

the same or another computer for later processing).

These devices may be located on or near a central operator's desk, or they may be placed throughout a plant at convenient places remote from the computer itself.

In normal operation, the operator receives data on performance of the process-computer system via the various recording and indicating devices and can modify system operation by inserting new constants or complete programs via a tape reader, switches, or other input devices. As indicated by the dashed lines, the operator can also monitor the sensing devices directly and, in emergencies, can assume control, running the process in the same way as before installation of the computer.

B. Functions

The conventional, one-variable controller executes what is known as "feed-back control." That is, a direct measurement of a product quality or process condition is made and used to initiate control action at an earlier point in the process to correct any deviation of the measured variable from its desired value. Information flows generally in a direction opposite to material flow in the process. Very little knowledge of the process is required to implement this type of control, generally only a knowledge that an increase (or decrease) in a manipulated variable will eventually restore the measured variable to its desired value.

In computer control systems, on the other hand, control is exercised to a large extent in a "feed-forward" manner in which disturbances are sensed and corrective actions are taken before the process has had a chance to be upset. These systems rely heavily on measurements of raw material characteristics and ambient conditions, rather than measurements of product characteristics as in "feed-back" systems. To exercise control in this manner, the computer control systems in the process industries must employ a set of process equations or a mathematical model to predict the effect of accidental or deliberate changes in process conditions.

The control calculations performed by a process computer often fit into one of three categories, identified by the following labels and explanatory remarks:

(1) *Status*—Where is the process operating now? (This class of calculations is especially significant when values of certain variables, which can be computed but not measured directly, are necessary as a starting point for other control calculations.)

(2) *Optimization*—Where is the best operating point? Or, alternately, where is a better operating point? (If repeated enough times, a method for finding a better operating point will eventually find the best operating point; if done rapidly enough, such methods can be as effective as one which finds the best operating point in a single step.)

(3) *Regulation*—Given the results of the optimization calculations or merely an arbitrary but acceptable operating point, how should the computer maintain the desired process conditions? If the process is not at its desired operating point because of a disturbance which is not measured and does not appear in the process equations, how should the manipulated variables be changed to return the process to the desired operating point? (For a process with numerous objectives, time lags, and interactions between the variables, the regulating function alone may constitute adequate justification for using a control computer.)

Control calculations are the most publicized element of the process computer's program. However, a process computer has a number of other essential functions which are described briefly in the following paragraphs, roughly in the order of occurrence during normal system operation.

In preparation for calculations, incoming data are generally subjected to individual limit checks to detect instrument failures or out-of-normal process conditions, converted from their original form into meaningful engineering units, averaged or smoothed to minimize the effects of random variations, and perhaps tested for reasonableness by comparisons between variables. Where a given variable can be calculated in several ways from different sets of data, the results may be used to obtain more accurate data or to detect instrument failure. Such calculations can also substitute for a desirable but presently nonexistent instrument.

Since the characteristics of any process change with time, control computers are usually programed to keep the process equations up to date by periodically revising some of the numbers in the equations on the basis of data from the actual operation. To a limited extent, these revisions are made automatically. More extensive modification of the process equations, based on data accumulated over a long period of operation, is usually left to an engineer.

Beyond its control calculations, the process computer can develop information for use by operators, technical personnel, or management. Examples are yields, efficiencies, and production costs—quantities not directly measurable but easily computed from the available data. Under some conditions, the process computer can perform other engineering or business calculations, using either parts of its control program or completely unrelated programs.

Sequence control has played a small part in most of the process computer installations to date. In the electric power industry, on the other hand, the start-up and shutdown of generating units is the primary control function. The computer carries the generating unit through a complex sequence of events necessary to light burners, actuate turbine-generator auxiliaries such as pumps and valves, accelerate the turbine, and connect the generator to the power system. Steps in the sequence may occur at fixed time intervals, upon reaching a specified combination of process conditions, or on a mixture of both. (Optimization of operating conditions plays only a minor part in computer systems employed in steam plants and nuclear reactor generating stations; several computers being installed for economic dispatching of complete power systems, however, have a significant optimization function.) Its facility at logical operations is important in other applications, nevertheless, since it permits the computer to react automatically to changes in objectives or process configuration (due, say, to a compressor breakdown) and to index a common program to serve similar process units.

Overall process-computer system reliability can be enhanced and downtime can be reduced by performing diagnostic programs at regular intervals. These programs can test that a fixed dummy input has the correct value, that an arithmetic program can be solved with the expected result, or that a dummy output can be converted correctly to analog form and read as a computer input. By checks on individual input signals or combinations thereof, the computer can also detect actual or impending process breakdowns; for example, major differences in flows at two ends of a pipe might indicate development of a leak.

Before operating any of the various output devices, the computer must carry out a number of data preparation steps: Conversion from the binary form used internally to suitable codes for operation of alphanumeric devices, such as typewriters and tape punches, collection of separate sets of data for transmission to each of the output devices, and arrangement of these data into proper formats.

As already suggested, the output communication devices can have many forms and perform many functions. Specifically, these functions can be:

(1) Alarm annunciation;

(2) Display of present values (one or several selected variables);

(3) Display of trends (one or several selected variables);

(4) Periodic data log;

(5) On-demand data log;

(6) Recapitulation of recent history (triggered by the operator or process event);

(7) Summary data log (for a unit or run of a particular product, a shift, or a day, etc.);

(8) Operator guidance.

Several techniques can be used for modifying process conditions:

(1) Adjustment of a controller "set point" to change the desired value of the flow, temperature, or other variable being maintained by the controller;

(2) Direct adjustment of a valve position, the result being sensed by some measuring device and transmitted to the computer which supplants the conventional controller (known generally as "direct digital control" or DDC);

(3) On-off or digital signals to actuate solenoid valves, to start or stop compressors, pumps, or conveyors, etc.

C. Installation Procedure

Sucessful installation of a complex industrial control system involving a digital computer requires a variety of talents. In situations where the user could not supply all the necessary skills and could buy only equipment from an outside supplier, joint user-vendor teams have been formed for system design and installation.

In joint projects, the user has usually assigned:

(1) An operating man familiar with the practical aspects of day-to-day operation of the process to be controlled;

(2) A process engineer or research man familiar with fundamental theory pertaining to the process;

(3) An instrument specialist able to supervise installation of measuring devices and their connection to the system;

(4) One or more people capable of computer programing;

(5) Accounting, quality control, operations research, or other specialists as required (on a part-time basis).

The equipment vendor has made available as members of the project team:

(1) A systems engineer skilled in planning computer control systems so they accomplish their intended functions;

(2) A hardware specialist who will be concerned with connection of the computer to measuring, controlling, and display devices;

(3) One or more programers experienced in writing programs for on-line computer systems.

The usual project team has, somewhere in its membership, a background in physics and chemistry, in all branches of engineering (chemical, mechanical, electrical, etc.) pertinent to the plant being controlled, in mathematics and statistics, in instrumentation and control, and in principles of computer application.

Users who have already installed one or more computer control systems probably now have a staff that can perform all of these functions. Many such organizations now issue specifications and buy control equipment in the same manner as other process equipment.

The design procedure starts with all members of the project team becoming familiar with the process equipment layout, material flows, and operating procedures.

An early step in system design, subject to later revision, is definition of the boundaries of the system and the functions to be performed. System boundaries may coincide with geographic limits of the process, include only a part of the process equipment, or extend to sources of raw materials or points of product utilization. Boundaries must be fixed with care so that actions beneficial to the area under control do not have detrimental effects elsewhere.

Process variables need to be listed and classified, and operating objectives must be specified properly. As mentioned earlier, system functions may include data processing in preparation for later use; calculations of yields, efficiencies, and other measures of process performance; calculations for control purposes; logical operations; diagnostic programs for checking the process or the control system; and generating output signals to control and display equipment. Planning for these functions occupies the entire project team; their programing can be spread over the duration of the project, with some of it beginning close to the starting date.

Development of the process equations and control relationships is a major step in system design. The original equations for a computer control system can be developed in two principal ways. In one approach, the equations are based on a combination of fundamental physical and chemical principles with specialized relationships, gleaned from research reports or published literature, appropriate to the particular process. In the other approach, operating data are analyzed by statistical techniques with little reference to other knowledge of the process. As part of this effort, the availability of instruments to measure process variables is checked; if necessary, the control scheme is revised to circumvent instrument problems. System design thus includes selection of variables to be measured and process conditions to be controlled, and development of the mathematical or logical procedures by which the control actions are related to the measurements. When this work has been done, detailed instructions for the computer can be written by the programers.

While this analytical work and programing is going on, other preparations are made for installation of the system. A site is picked for the control equipment, new instruments (if needed) are installed, display and communication devices are mounted, and signal lines connecting all of the equipment are put in place. When the computer is delivered, it is connected to its input devices and its ability to receive data is checked. The control program is tested using the actual process measurements, the suggested control actions being displayed for approval by operating personnel. When everybody is satisfied that the system works properly, it can be placed in full automatic control of the process.

Although specialized abilities of a high order are needed for system design, routine operation of an advanced electronic control system is possible with operating personnel having the same general level of skill as were employed previously. It is not necessary that they have engineering degrees or understand the internal operations of the computer or other electronic devices. These people receive special instruction in the procedures needed to start, run, and shut down the new system.

When the computer control system is operating, a service or maintenance specialist is necessary. The supplier can furnish a man on a contractual basis, or the user can have one of his own men trained to carry out this function.

D. Justification

To many users, a control computer is viewed as a means for putting management in real charge of the operating process. If a particular operating policy is desired, it can be built into the computer program and executed around the clock, even when the responsible management people are out of the plant. In the same fashion, research workers can insure that process conditions are held constant or are deliberately varied over a range of acceptable values to give them new data for testing theories or improving the mathematical model of the process. A computer control system represents an advance over previous techniques because it allows the continuous application of the most advanced knowledge of process behavior rather than the simplified procedures and control schemes that would otherwise have to be employed.

Investments in these advanced control systems are being justified by several kinds of benefits:

(1) Increased production;

(2) Improved control of product quality;

(3) Better use of raw materials, catalysts, solvents, electricity, fuel, and so on;

(4) Reduced maintenance;

(5) Greater safety for personnel;

(6) Reduced manpower;

(7) Better technical and accounting data;

(8) Increased process knowledge.

Although reduced labor costs are a potential source of benefits, manpower reductions have played a negligible part in justifying advanced control systems for plants which already use automatic control devices in great numbers; managements of process plants have not looked upon labor savings as the primary reason for installing a control computer.

Managements have not abandoned their customary interest in dollars-and-cents issues in favor of an altruistic advancement of technology or unquestioning adoption of the latest techniques. In an unpublished article on automation, a writer stated:

> There's a crucial distinction between what is scientifically or technically possible and what is economically feasible. We have the scientific and technical capacity to do almost anything. But which of this almost infinite array of possibilities will in fact be done, and when, depends on the complex and always-changing relationship between the costs of doing them and the benefits that are likely to accrue.

This paragraph describes very well the attitude of potential users of advanced control techniques.

The conventional analog controller is now installed without much regard for its cost, and the simpler analysis instruments are installed with only a little more thought. However, as with any other major process improvement, a computer control system is expected to pay for itself in a reasonable time interval. At various stages in the design of a computer control system, its costs are therefore compared with the expected benefits in order to judge the attractiveness of the investment.

The direct cost of a computer control system is composed of several elements:

(1) Computer and associated peripheral devices (including logging and alarm typewriters, tape and/or card readers and punchers, input selector, analog-to-digital converter, and so on);

(2) New instruments and analyzers;

(3) Transducers for connecting new and existing instruments and analyzers to the computer;

(4) Equipment for connection of the computer to actuators (such as analog controller set points or valves);

(5) Wiring, instrument air tubing, conduits, and so on;

(6) Special consoles and devices for operator-computer communications;

(7) Site preparations (such as space to house the new equipment and air conditioning);

(8) Engineering effort and other labor directly associated with equipment planning, design, selection, testing, and installation;

(9) Technical effort for developing process equations and control schemes;

(10) Programing;

(11) Project administration (for coordinating schedules, costs, and documentation);

(12) Training;

(13) Maintenance.

At the present time, the cost of a computer control system can be expected to fall between $200,000 and $400,000, possibly more for an unusually large system. The cost of the computer itself, item (1) above, is $50,000 to $150,000 [1]; the remainder of the system cost arises from the other items in the list. In most cases, process management demands annual benefits equal to or greater than the system cost before approving its installation.

In the early stages of system design, before mathematical models of the process are developed, it is impossible to make any accurate predictions of the benefits to be expected; only rough guesses can be made. One can, for example, examine operating records to determine the difference between presently observed yields and theoretical maximum yields. If this difference is small, its complete elimination might not justify a computer control system. If it is large, however, and grounds can be found for thinking that a computer control system would reduce the difference, further effort on system design is at least warranted. Similar considerations apply to operating costs which might be reduced by installation of a control computer.

After the process equations and control scheme are developed, more exact estimates of expected benefits can be made. At this point, it is possible to simulate process operation mathematically. The procedure consists essentially of collecting data for a representative period of past operation without the computer control system and calculating what the yield, production rate, product quality, and important operating costs would have been if the computer control system had been working. If repeated enough times to reduce the possible misleading effects of errors in the data or an unrepresentative selection of data, this pro-

[1] Since the price range for general-purpose digital computers is roughly $20,000 to $5,000,000 or more, the process control computer is seen to be a relatively junior member of the family. When applied to a process computer, the term "giant brain" is wrong on two counts: It is not a giant and it is not a brain.

cedure gives as good a prediction of expected benefits as can be obtained. At this point, system costs can be estimated with considerable accuracy, and the economic justification for installation can be judged with some confidence.

Improvements in product quality, another potential source of benefits, may be difficult to translate into dollar earnings. In some cases, if off-specification product entails a direct cost for scrapped material, reprocessing, or transportation from a customer back to the producer, estimates can be made by examination of past records. On the other hand, if better quality is expected to lead to getting a larger share of a limited market, the resulting dollar earnings may be largely guesswork. It should also be noted that inadequate control of a process, which often leads to wide variations in product quality, may result in the average product quality being held at a high level so that the lowest quality material produced will meet specifications. Tighter process control in such cases would mean a reduction in the quality variations, permitting a lower average quality and consequent savings in some operating costs.

The most accurate measure of system justification is gained, in principle, following installation when actual benefits and costs are available. However, in practice, actual values are not easily obtained. In several cases, simultaneous process modifications have clouded the picture: New reactors were added, another compressor was installed, or a better catalyst became available. New instruments may be developed and marketed while the control system is being designed, and their use will itself alter process performance. Any changes of this type will improve process operation, and isolation of improvements properly traceable to the control system is rendered difficult or perhaps impossible.

In some cases, changes in raw material characteristics or availability have radically altered process performance. Changing market conditions have sometimes required a shift in computer objectives from maximizing production to minimizing costs (or conversely), necessitating revision of the computer program and invalidating any historical comparisons.

Even without these changes, difficulties are encountered. Because processes are already operated reasonably well, the benefits to be expected are often not great; for example, 2 to 5 percent is a typical estimate for an improvement in yield. Process measurements are frequently subject to errors of the same magnitude. As a result, a chance exists that a small number of measurements will show a loss in process performance even though an improvement was actually realized. Collection of data over a long period of time may be needed to separate real improvements from random variations. As would be expected, the smaller the average improvement and the greater the measurement errors, the larger the number of data needed.

Although costs are reckoned more easily, great precision can seldom be obtained. For example, accountants do not always agree on the allocation of engineering or equipment costs to the computer project. Some process analysis and computer programing might be considered normal duties of a process engineer. Some instrument changes or process modifications might have been made anyway. What fraction of these costs should be charged to the computer control system?

Each company contemplating installation of its first process computer must go through the justification procedure for itself because data on the performance of installed computer control systems are hard to obtain. If a system is really profitable, a user doesn't want to advertise the fact to his competitors; if it's marginal, he is too embarrassed to say so; and if it's a real dud, he ships it back to the vendor, usually without any fanfare. Proprietary and psychological considerations thus interfere with free exchange of information; except for publicized instances of multiple installations by its competitors, a company gets little indication of the success of process computers within its own industry. This problem is alleviated, of course, when a company can look at the performance of its early installations in justifying later ventures.

A number of companies have gained their first experience with process computer control through an installation for an existing or "old" plant. While costs are higher for adapting plant instruments to the computer, this approach has the advantage that operating data are available for system design and justification. On a "new" plant, electronic instruments can be specified which allow easy connection to a computer. However, plant startup may be delayed by competition for manpower between computer system and basic equipment design, or by actual interference with construction work, and completion of the computer system must be postponed until operating data are available. The impact of the computer system on operating manpower requirements is obscured because no "before" and "after" comparisons are possible and other innovations will affect crew size. While a sizable fraction of the plants constructed in the future will incorporate a process control computer, installations in older plants will also continue as an element in modernization.

The incentives to use process computers on new plants are not so overpowering that all new plants will have them, and the difficulties in old plants are not so great that none will have them.

E. Present Status

Approximately 20,000 digital computers are installed around the world for all applications, about 90 percent of them in the United States. Of this total, only 2 to 3 percent, or 400 to 600 digital computers are installed or ordered for process control applications, again a substantial portion being in the United States.

Table 1 shows process computer installations in the United States by industry and year, and table 2, process computers around the world. Both tables are indicative of the extent of process computer utilization at the end of 1964.

These tables are based on similar summaries which have appeared in trade journals,[2] news items on individual systems, and a limited amount of personal knowledge. The numbers reflect both orders and installations; in general a system is listed under the year in which its existence was first announced or became known. In compiling the figures, an effort was made to count only process control applications, excluding computers used for such miscellaneous purposes as toll collection, production testing, TV switching, medical and psychological data collection, newspaper typesetting, and so on; partial and probably inaccurate figures for these miscellaneous applications are, nevertheless, shown in the first table. If the totals in both tables are smaller than figures published in the trade journals, two primary explanations can be offered: Installations claimed by manufacturers but not identified have been excluded, and totals claimed by American maufacturers have been sifted to remove oversea installations which are occasionally counted to improve their relative position in the standings.

[2] See, especially, *Control Engineering*, May 1962, pp. 79, 81; September 1963, pp. 73–83; March 1965, pp. 57–62; and August 1965, pp. 54–59.

TABLE 1. PROCESS CONTROL COMPUTERS IN THE UNITED STATES

Industry	Year							Total
	1958	1959	1960	1961	1962	1963	1964	
Power	1	1	9	9	18	33	30	101
Steel	------	------	4	12	8	8	29	61
Chemical	------	2	7	7	11	7	24	58
Petroleum	------	2	------	6	7	3	9	27
Pulp and paper	------	------	------	1	3	7	5	16
Cement	------	1	------	1	------	4	8	14
Pipelines	------	1	------	1	3	2	5	12
Nonferrous metals	------	------	------	------	------	1	4	5
Glass	------	------	1	------	------	------	2	3
Foods	------	------	------	------	------	1	2	3
Textiles	------	------	------	------	------	------	3	3
Total, all process control installations	1	7	21	37	50	66	121	303
Miscellaneous applications	1	3	3	14	3	9	22	55
								358

TABLE 2. PROCESS CONTROL COMPUTER INSTALLATIONS AROUND THE WORLD THROUGH 1964

United States	303
United Kingdom	46
Japan	38
France	32
Italy	14
Germany	10
Canada	6
USSR	6
Holland	3
Belgium	2
Sweden	2
Austria	1
Australia	1
Spain	1
South Africa	1
	466

3. User Experience With Respect to Manpower Effects

Limited time and resources precluded making an exhaustive survey of the manpower effects of process control computers. However, inquiries were sent to a number of major users, and useful replies have been received from many of them. In all, the organizations responding account for about 30 percent of the digital computers installed or ordered for process control applications in the United States. The experiences of these users should provide a reliable guide to the overall manpower effect of all installations to date and a basis for predictions about the future.

A. Procedure

To obtain firsthand information on the employment implications of process control computers, letters were sent to a number of chemical, petroleum, steel, and power companies known to be major computer users. The letters contained the following requests:

> For each of the control computer installations made by your company, I would like to know the size of the operating crew "before" and "after." The number can be expressed as men per shift or as a total, it being understood that 4 (or 4.2) men are needed to fill one position on a round-the-clock, 7-day-a-week basis. Where a change has occurred, some explanation would be helpful. For example, did the logging functions eliminate clerical work? Did a new analytical instrument, installed concurrently with the control computer, eliminate a man doing chemical analyses? Or did the total staff grow because engineers, programers, or maintenance men were added? Has the level of skill or training been changed?
>
> In addition to this past or current history, your candid opinion about future directions is also solicited. Will manpower savings play a bigger role in the next installations? Why? What technical or economic factors will be responsible?
>
> I hope you can supply this information without spending a lot of time getting high-level management or public relations approvals in your own company. (If the point under discussion has already been covered in your publications, reprints or copies would be handy.) In using the material, I definitely will not identify the source without permission but will refer only to "a control computer user" or will employ some equally anonymous designation.
>
> I would like very much to discuss this topic with you personally but fear it is impossible in the time available, so that a letter will be necessary. If an off-the-record telephone call would be preferable from your viewpoint, please feel free to call me.

The last two paragraphs were included because it was expected that many companies would view employment effects as a sensitive issue. These expectations were confirmed by one man with a major petroleum company who wrote:

> Unfortunately, present company policy does not permit me to furnish any of the information you need. Recent high-level instructions are quite explicit about information of this type—which also preclude an off-the-record telephone call as you suggested.

About one-third of the men to whom the letter was addressed replied by telephone, and one man sent his reply on plain paper rather than his company letterhead. Nearly all of the people responding have asked that their organizations not be identified.

B. Replies

In response to a total of 22 letters, 20 replies have been received, leaving 2 companies which have not answered. One company acknowledged the inquiry but replied as follows:

> We have given considerable thought to your request to supply figures on the effect of computer control. As you know from your experience, this becomes a rather complex question involving the manpower contributions of various groups . . . . We have so many urgent projects . . . that we do not see our way clear to undertake such a survey for you.

In summary, the numbers of inquiries and replies have been as follows:

Industry	Sent	Received		
		Letter	Telephone	No reply
Chemical	7	4	3	0
Petroleum	7	6	1	0
Steel	4	1	2	1
Power	4	2	1	

Following are pertinent portions of the replies.

Chemical

(1) From a chemical company with two process control computers:

> In one plant, we combined installation of a process computer with a complete rebuilding of our instrumentation. At the same time, we consolidated two control houses into one, and brought in two outside control panels from each unit. All told, we cut 10 different panel locations down to 1.
>
> At the start, we had six operators per shift. Now we have five. The computer had nothing to do with it.
>
> We get more data, more quickly, and in better form.
>
> Our chemists have more work to do, not less, and there has been no reduction in the number of lab people.

Our total staff is up about 2½ people for process analysis, programing, and maintenance.

In the other plant, there has been no effect on employment; no operators taken off, no technical people put on.

I don't expect any future manpower reductions. New processes and products can't wait for analysis and programing to put the computer in when the plant is built. There won't be any pushbutton control from the front office.

(2) From a chemical company:

Like all capital investments, a process computer has to pay back in line with the investment policy of the company. This pay back can come from various areas:

(1) Replacement of people.
(2) Greater product value by virtue of more uniform product.
(3) Greater process efficiency, less loss, higher running rates, etc.

Item (1) is unrealistic. Mechanized processes operate now at an irreducible people level from an equipment safety viewpoint. In fact, those plants building up in this area have net increases in employment for maintenance of the computer and associated electronic gear, and at professional levels. We have seen no decrease in employment as a result of process control computer effort.

Installations to date have not reduced a single person per shift from a manufacturing operation. The increase in electrical engineers, computer technicians, programers, and systems engineers is substantial and is being felt at both staff and plant levels.

Item (2) is very real and has no implications on employment.

Item (3) continuously goes on in any corporation wishing to remain in business. It has been accomplished by traditional means of mechanical engineering, metallurgy, operational analysis, process research, etc. We now add to this list an effort whose equipment and qualified people are relatively new. Perhaps despair should be aimed at "excellence" in manufacturing, for it is hard for me to distinguish the difference in total effect between process computer control and the more traditional areas of past (and current) effort.

(3) From a talk by an engineer with a chemical company that was an early user of computer control:

The "science fiction" writers of the popular press, however, usually single out computers or "electronic brains" as their favorite subject. Invariably, the computer is blamed (or credited) for the wholesale replacement of labor. But if these writers did research with the same zeal they exhibit in heaping abuse on computers, they would be aware that the computer's greatest application has been in clerical areas affecting mostly white-collar workers, not blue-collar workers. As the percentage of white- to blue-collar workers is increasing, other factors must be more than compensating for labor effects of data processing equipment. It is also probable that there has been no wholesale replacement but rather a nearly equal substitution. In any case, my task is to describe our use of computers, primarily for control purposes.

. . . by 1958 the "labor" automation of a modern chemical or petroleum process was relatively complete. The evolution toward automatic control has possibly moved faster in the chemical industry because the major variables are easier to control. What did we hope to gain by adding a computer? Labor costs, obviously, was not a consideration. Our primary goal was increasing product quality and speedier adjustment of variables resulting in loss.

. . . Since early 1960, a steadily increasing number of computers have been installed for this use. In general, these systems are designed to apply preplanned intelligence to the overall economic operation of the process. The desired result was to increase production, reduce amount of raw materials, improve product quality, or possibly all three. The number of people required to operate a computer-controlled process is usually not affected. They remain, in redefined roles, ready to assume control should the equipment fail or if a situation not provided for comes up.

What are some of the conclusions after 4 years of operation? . . . "Labor savings," as predicted, will usually not be a factor for this particular type of automation.

(4) From a chemical company with several installations:

In one of our computer control installations, an installation with several process steps, the operation is controlled on a one-shift position basis (one man for four operating shifts). No reduction in manpower is possible, partly because the computer project was chosen on that basis. The job is much easier now for the present operator, and it is contemplated that the chief justification will come from increased productivity on the part of the man, increased yield, and increased effective working capacity. We have an on-line analytical instrument on this installation which eliminates an infrequent wet analysis by the operator.

In another project, similarly manned on a one-shift position basis, with on-line analytical instrumentation, the computer data logs more frequent and up-to-date information which primarily means better cost control of the process. No manpower reduction is contemplated, but there is more process information available, and further, the operator controls more process equipment as the plant has expanded in two stages in the past 4 years.

In another batch control operation, a new process, we can say that more men would have been required if the processing steps were not automated. But the new operation will create new jobs.

In one area only can I see a possibility of manpower savings. This is in the area of information systems, or overall plant control. Direct processing of information will reduce clerical type positions, but at least in part will be balanced for an increase in cost analysis as more and better information is processed.

Obviously, today the experimental nature of these installations has increased manpower—engineers, programers, maintenance personnel, and the like. Management has not allowed the situation to get out of hand, however, and has only authorized increases where projects were justified.

I can sum this up by saying that the chief purpose in utilizing process computers in plants should be to increase productivity—yields and capacity—and not to reduce manpower.

(5) From a chemical company with several process control computers:

Labor saving is not much of a factor, because the computer-logger is used where labor is "at an irreducible minimum for safety reasons."

The computer collects data cheaply. It gives information you wouldn't get if you had to do it with clerks because it would cost too much.

There is no question that added technical people outweigh any drops in operating personnel. Widespread use of computers will mean changing the content of engineering training. We would like to get more qualified people, but we have trouble finding them.

(6) From a chemical company with more than half a dozen control computers:

Over a 4-year period, we have reduced our total operating crews from 63 to 43 positions per shift. [This reduction would mean 20 positions or about 85 jobs on a round-the-clock, 7-day-a-week basis.]

We attribute the reduction to better process surveillance and alarm scanning, data logging, and the reduction of data to meaningful terms and its presentation in time to be useful. After installation we found we had too many operators for the work to be done; *some of them asked to be transferred to another unit.*

We have had to increase our engineering staff and have also created a new plant position: A "computer specialist" who is an engineer with a control and chemical engineering background. These increases did not make up for the decreases in operators.

(7) From a chemical company which has been one of the front runners in the use of process control computers:

. . . our management is extremely sensitive to public discussions of automation and manpower savings. Let me therefore speak only as an industry representative and not from [my company's] viewpoint alone. . . .

My impression is that our industry is in as strong an automation program as any other you could name. This work has had a relatively minor effect on manpower in the past because computer control systems were mainly supervisory in nature and thus supplementary to the regular task of the operating staff. In addition, standard control along with sequential relay systems had already reduced the industry manpower nearly to the emergency operations level.

A decided impact on manpower is dependent mainly upon our ability to eventually solve the extremely difficult automatic startup, shutdown, and turnaround problem. Once this is solved, however, computer control systems, consolidated control rooms, and "flying squad" maintenance and emergency operation procedures could significantly reduce our manpower requirements again.

Petroleum

(1) From a petroleum company with two process computer installations:

We did not decrease our operating personnel as a result of installation of the [computer].

Our total staff increased, particularly with regard to additional maintenance manpower to service the peripheral equipment associated with the computer.

The sophisticated nature of the equipment involved in computer control required a higher skill level on the part of our maintenance people.

We do not believe that manpower savings will play a bigger role in any future installations. Most of our refinery installations, operating without computer control, are highly automated and, as a consequence, the addition of computer control would accomplish very little in the way of reducing manpower.

We feel that the savings that may be obtained through the installation of process computer control will result from . . . improved yield distribution, smoother and safer operation, increased unit capacity, decreased utilities, improved product quality, and so on.

(2) From a petroleum company:

It is our company's policy not to release information on the size or function of crews on operating units. However, we can say that in [the company's first] installation no manpower savings resulted . . . . Also we do not expect any manpower savings from the [second] installation under development for [another refinery]. Justification for both of these installations has been entirely on providing an additional tool to the operators for their improved control of the process.

(3) From a major petroleum company:

We have three active installations which did not replace people and were not expected to. They were installed for rapid correlation of data. A technical man devotes part of his time to the supervisory control computer, but he is not a new hire.

Like many other refiners and chemical companies, we are making a number of "control house consolidations," some with computers and some without. These may cause a considerable manpower reduction which is really due to general improvements in data transmission and control techniques. Some people will credit the computer with the reduction but it's actually just a piece of the project. By itself, it makes no real difference.

(4) From one of the large petroleum companies:

We are happy to have the opportunity to "help set the record straight" with respect to the effects on manpower of process computer control. In no case have manpower savings been used as an incentive for the installation, and in no case have we reduced manpower or have we been able to see a significant change in the amount of work done by the operating crews. The computer may save some logging time, but at least as much time is required for the operator to enter information and act on the instructions from the computer.

During any application a good deal of engineering and clerical time is required. After the application, engineering (technical service) time is at least equal if not more than before. Conventional and special analytical instruments have increased maintenance work somewhat, but so far there has been no change in the number of maintenance people.

(5) From a petroleum company:

As you well know, my company has installed two computer control systems for process units. In each case the new process units were part of modernization programs, and jobs were eliminated because single large units replaced several smaller ones. However, to call this technological or automation unemployment is similar to complaining that jet airplanes have created technological pilot unemployment because they carry more passengers faster than DC–3's. As far as the computer installations themselves are concerned, I am sure you are well aware that these do not result in any reduction in the staffing of the two units. The "X" unit requires three men per shift, and the staffing would be the same with or without the computers. The "Y" unit also requires three men per shift, and this also would be the same without the computer. The entire justification of the computers lies in improved efficiency of operation of the units. In other words, we hope to reduce cost for raw materials and utilities and to improve the value of the products from the unit. In fact, you could say that the computers have increased employment in our business because they have created employment for computer engineers and skilled electronics maintenance men, and have increased the level of maintenance on the associated instruments.

With regard to the future, I personally see no significant loss of employment resulting from application of computers in processing industries. The major brunt of computer-caused unemployment has been in the accounting areas, and most of this has already occurred and has been absorbed by the economy. The popular press turns out a lot of copy about the automation revolution, but as you know, it greatly exaggerates the results and almost ignores the staggering technical problems involved. Certainly you can automate almost any task in the world that is being done manually, but the time and expense involved in doing so would be ridiculous in most cases. I see little prospect of this situation changing very rapidly.

I can get quite upset from reading the hokum that some of the social planners write about technological unemployment being a threat to our civilization, particularly when the same people simultaneously bemoan the poverty and substandard living conditions of a large part of our population. Since our average standard of living is simply the national production of goods and services divided by the population, I do not see why the social planners should not be enthusiastic about any kind of increase in productivity—at least until everyone has as high a standard of living as he desires.

Steel

(1) From a steel company:

We have four control computer systems installed or being installed. At our first installation, we added one man in a supervisory position who was trained in computer operation and programing.

On one rolling mill, we have one less operator, but this reduction is due to a continuous gage control system, not to the computer. One clerical job may be eliminated in the future. However, in the long run, we may have a net addition, because we have trained two service people and two programers.

On another new rolling mill, the operating crew will be smaller because of better mill design. The losses will be laborers, not operators. We have extra men around the furnace, because it's necessary to keep track of the position and identity of the material about to be rolled.

Our fourth computer is just going in, and we can't say anything about it yet.

In general, I believe it will cause a transition from shift work to day work.

(2) From a steel company:

As far as I know, the installation of process control equipment has not reduced manpower requirements but has increased them and, also, raised the level of skill required. This is a positive statement as far as the blast furnace and basic oxygen steelmaking installations are concerned.

[Unfortunately, he does not comment on his company's installations for several rolling and processing operations.]

I believe that this will continue to be the case with process control. The man-hours per unit of product will decrease because of increased production and/or reduced rejections, but the total number of people employed will usually increase.

(3) From a steel company with several computers:

In general, we don't find much labor saving in putting a computer on an existing part of the steel mill. We have to have somebody around to take over in the event of a computer failure. The economic justification is based on better productivity, yield, and quality.

For new plant facilities, we have smaller crews because they are more mechanized. For example, in our oxygen steelmaking shop, the savings will come from better material handling. Also, we're bringing data from the scales, the chemical lab, etc., into the pulpit for monitoring by one man. The computer itself doesn't replace anybody; the system must and will operate without the computer.

On a strip mill, only 2 percent of the justification came from a manpower saving—one man who worked around the finish end and didn't do much of anything anyway.

Some incentive systems will cancel out any increase in productivity; costs may be more inelastic than people think.

Power

(1) From a power company with several computers:

We do not consider this a touchy subject.

All but two of our systems are just loggers. At one station, two computers control two units from a single control room. Here we have eliminated one "outside man" per shift (out of four), so we now have about 5½ men per shift: three outside men, two operators, and half of a supervising watch engineer.

The outside man was eliminated because he didn't need to rove around the plant to inspect the equipment; scanning is done by the computer.

We have gained a position—"supervisor of instrumentation"—who looks after normal control equipment, keeps the sensors in good calibration, does diagnostics on the computer, and writes short programs. These are men we already had—three in all—who were sent to computer school, basically instrument-technician-type people.

(2) From a power company:

Our [computer] installation at [one of our steam stations] did enable us to reduce by one operator per

5

shift to a four-man crew for two units; however, we found it necessary to employ additional men in the electronics maintenance area and have had to upgrade the quality of our electrical maintenance people as a result of the computer installation.

It is my opinion that the computer installation in its present form which controls the turbine on startup and shutdown does not reduce manpower, but does give us a better control over our equipment, and gives us improved quantity and quality of information about our power station. Through the use of this information it is possible for us to get a better operating control over the factors which influence performance efficiency, thereby resulting in saving considerable quantities of coal.

(3) From a power company:

Unfortunately, we cannot make a direct comparison before and after computer installation due to the fact that the plant was initially designed with a computer. Also, we cannot honestly compare this station with our others due to extensive design changes which are totally unrelated to the computer. The computer does, of course, eliminate many menial operator functions, such as logging, changing recorder charts, and checking local instruments. However, the elimination of these functions does not necessarily result in a change in manpower requirements but rather releases the operator to concentrate on more useful functions.

With reference to maintenance personnel, again we do not see any change in the number or type of people required. Our instrument and controls maintenance personnel consists of [a graduate engineer] and three [assistants who are at least graduates] of a 2-year technical school. We consider the computer to be just another instrument and trained one of the assistant engineers at the manufacturer's computer maintenance school. I might add that the maintenance of the computer is practically nil.

It is [company policy] to do all of the computer programing ourselves . . . . All of our programing personnel are graduate engineers and have been "hand picked" from our General Engineering, Production, and Operating Departments . . . . The programing required approximately 6 man-years.

C. Conclusions From the Replies

Based on these user comments, one may conclude:

(1) Many user companies did not expect and have not seen any reductions in the number of operators as a result of process computer installation because their processes were already highly automated.

(2) Installations are justified, as described in section 2, by increased plant capacity, more uniform product quality, greater efficiency or yield, reduced waste and losses, and safer operation.

(3) Where changes in operator employment have occurred, they are attributed to control room consolidation, larger and better-designed new process units which can be operated by smaller crews, other equipment changes, or to the scanning and data-gathering functions of the process computer, not to its capability for better process control.

(4) One chemical company claims an average reduction in operating manpower of two shift positions (or eight men) per process computer. Other companies have experienced no reduction or, at most, one shift position (or four men) per process computer. Because many process computers have caused no change in the number of operators, the average effect on employment is perhaps one employee per computer.

(5) In most cases, technical and maintenance staff employment was increased; frequently, these changes offset the reductions in operating positions.

(6) By virtue of (5) and the training given to operators working with process control computers, the general skill level of the user companies has increased.

Although the user survey was not exhaustive and did not include a majority of the existing installations in the United States, the views expressed are consistent with the experience of other user companies. Based on personal observation, there is no reason to expect that different conclusions would be reached as a result of a more comprehensive survey.

D. Extrapolation to All Installations

Based on the experiences of a number of users reported in B above and figures presented in section 2E, extrapolations can be made to estimate the overall manpower effect of all process computers to date in the United States.

With one exception, the illustrations in this section are based on data presented in *Technological Trends in 36 Major American Industries*, a 1964 publication of the Department of Labor, extended by more recent data furnished by its Bureau of Labor Statistics. The top part of each chart gives employment figures in thousands; the top curve is the total number of employees; and the lower curve is the number of production people. In the center of the figure is a production index defined as 100 for the period 1957–59. The bottom graph shows the year-by-year growth of process computer installations, as well as it can be determined from published information; the number plotted is the cumulative total through the particular year, as determined from the previous table.

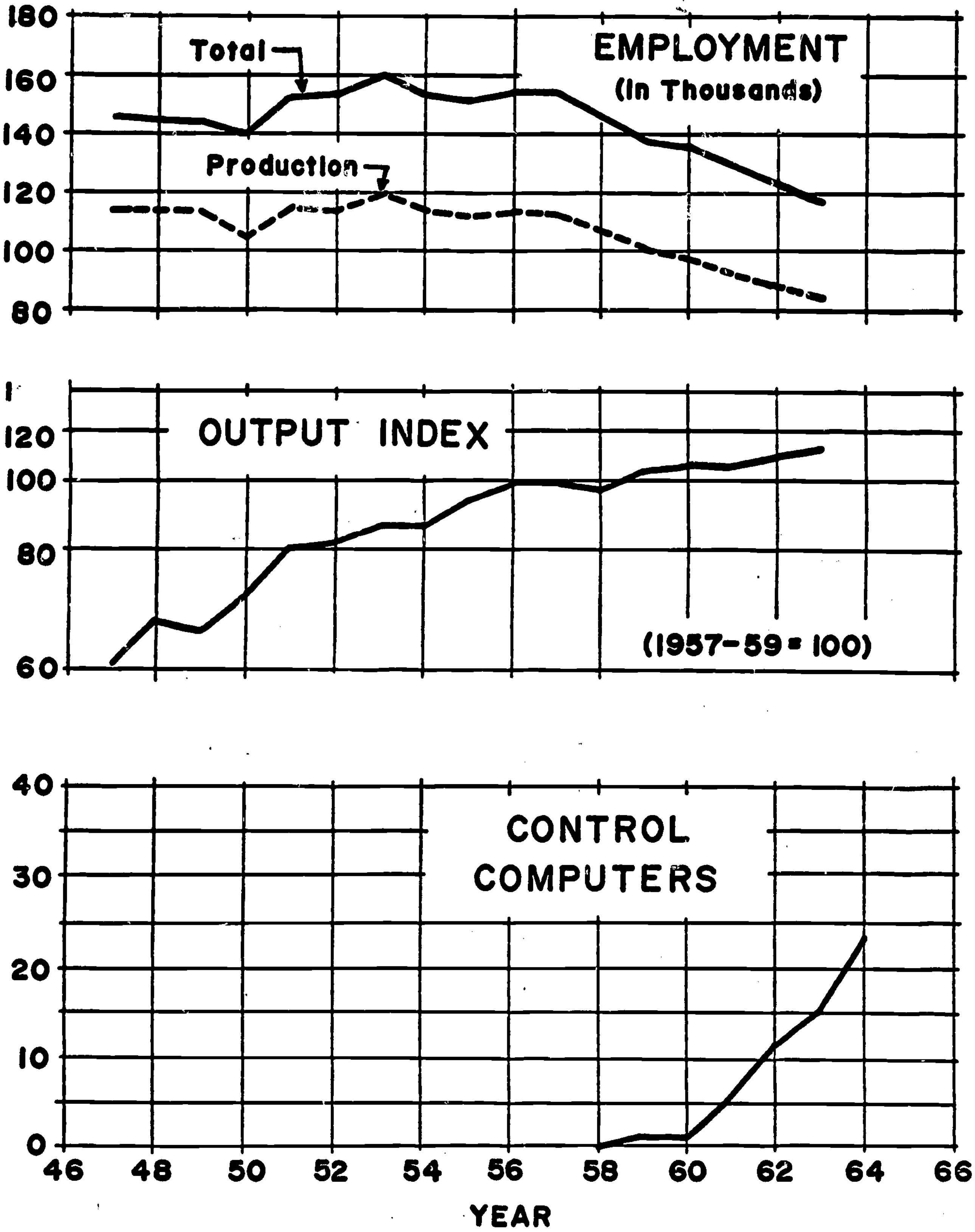
Because the chemical industry is not included in *Technological Trends*, the graph showing employment trends in this industry is based on tables C–1 and C–2, pp. 233–234, of the *Manpower Report of the President* and a *Report on Manpower Requirements, Resources, Utilization, and Training*, prepared by the Department of Labor and transmitted to the Congress on March 5, 1965. The two publications evidently use a different basis for compiling the data, because figures for "Petroleum Refining" in *Technological Trends* do not match those for "Petroleum and related products" in the *Manpower Report*. However, the employment figures for "Chemicals and allied products" from this report should reflect roughly the same segment of industry included in the tabulation of process computer installations; indicated changes probably have the correct direction if not the correct magnitude.

Petroleum

In petroleum refining, as shown in chart 1, one finds a generally rising level of production from 1947 to the present, and an almost steady drop in employment from about 160,000 in 1953 down to about 119,000 in 1963. The number of nonproduction employees has remained relatively constant at about 40,000.

Process control computers were introduced in 1959, and there are now about 2 dozen of them. It is evident that the drop in production employment began too early and is too large to be explained by the number of process control computers. Between 1959 and 1963, production employment dropped from 100,000 to 85,000; at the end of 1963,

CHART 1. *Petroleum Refining*



approximately 15 computer systems were installed (or ordered). *If* this drop were due entirely to introduction of process control computers, it would mean 15,000÷15=1,000 employees per computer system, a completely impossible figure in view of reason, personal observation, and testimony from users. It would be more reasonable to guess that each computer system displaced, at most, 4 operators for a total of 4×15=60, an insignificant part of the total change; even this figure is probably high.

The observed drop in employment has many causes, one of which is simply that petroleum refiners discovered that units had gradually become overstaffed and took corrective measures. It is due, in part, to use of larger processing units which can be operated by the same size crews as the older, smaller ones. It is due also to consolidation of control rooms, a measure which may have some connection with control technology in general but only a limited connection with the process control computer as such. Other types of automation, such as conveyors and forklift trucks used in packaging operations, probably play a part.

Based on present costs and capabilities of computer control systems and the market situation facing the petroleum refiners, one can estimate the number of installations now feasible in a technical and economic sense. Using published data on domestic refinery units and their capacities (*Oil and Gas Journal*, Apr. 5, 1965, pp. 157–177), about 250 computer control systems could be justified for existing facilities. If this figure is accepted, then the petroleum refiners have installed computer control for about 10 percent of the possible applications.

Companies supplying data on the employment effects of their process control computers have a daily crude oil capacity of 4,300,000 barrels, compared with an industry total of 10,700,000 barrels, so they represent about 40 percent of the industry. These companies account for slightly over half of the process computer installations in the petroleum industry.

Chemical

Production employment in the chemical industry has remained remarkably constant from 1951 to 1964 (see chart 2), varying from 502,500 in1951 to an estimated 528,600 in 1964, with a dip to 493,-700 in 1958. In the same interval, total employment has grown from 707,000 to 877,100. No output index is available, but it may be assumed that the growth in total employment reflects people added to cope with an increasing volume of business.

Process control computers were first adopted by the chemical industry in 1959, and about 60 had been installed or ordered at the end of 1964. In this interval, production employment increased slightly from 505,600 to 528,600, a difference of 23,000. Again, *if* the average process control computer had displaced 4 operators, the effect on employment would have been 4×60=240 operators, or about 1 percent of the observed change. In general, the impact of the process control computer is obscured by industry growth.

The chemical industry reported sales of $36 billion in 1964 (*Chemical and Engineering Progress*, January 1965, p. 30). Because of the many products and plants, it is impossible to count directly the number of potential applications for process control computers. However, a very rough estimate can be made in the following way.

Any process with an annual product value greater than $5 million can be considered a candidate for a process control computer system, since typical improvements of 3 to 5 percent should produce $150,000 to $250,000 per year in benefits, enough to pay for a system in a year or two in accord with accepted industry payout criteria. At an upper limit, 36,000÷5=7,200 such processes would be expected to exist.

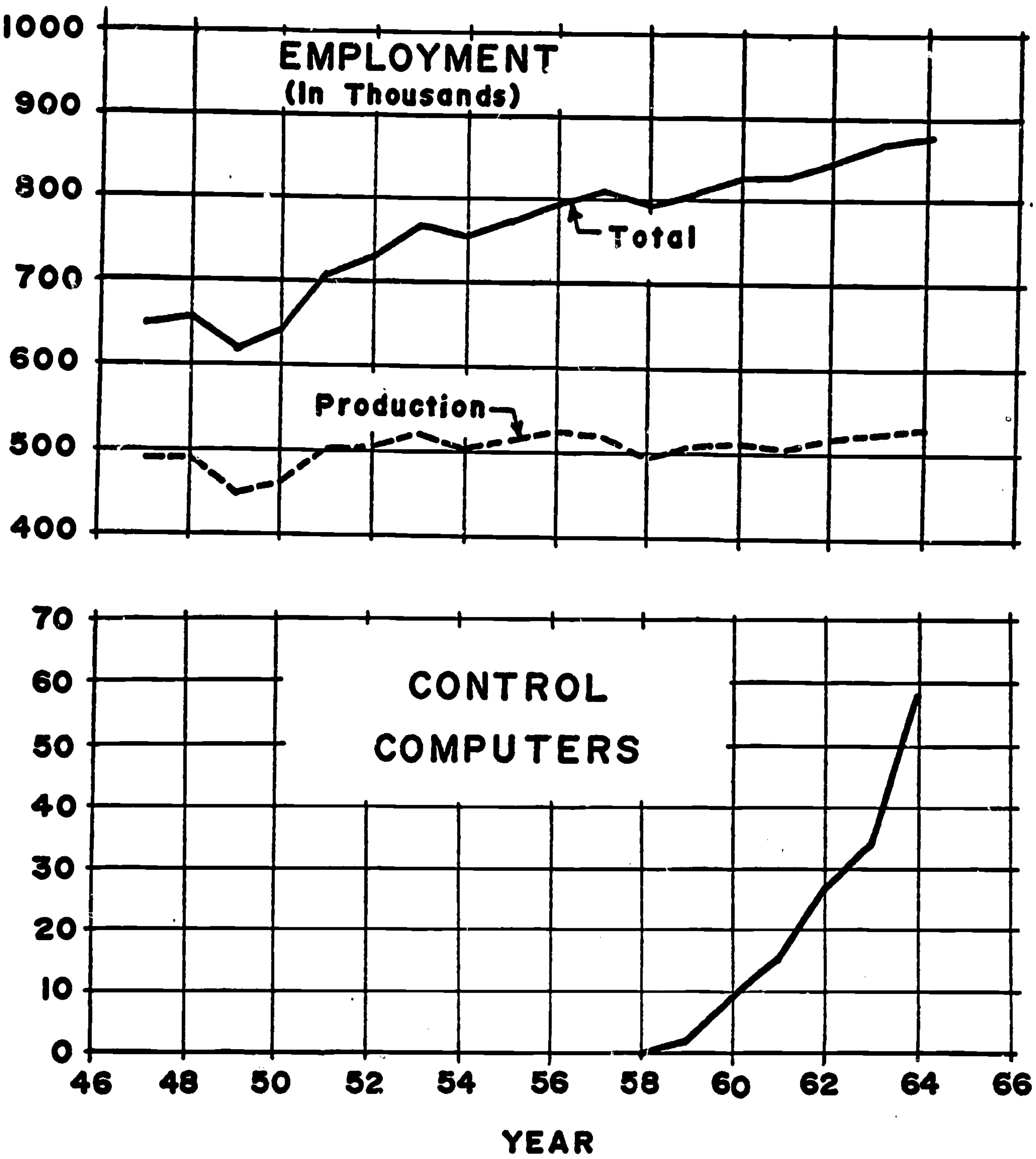
This figure overestimates the number of potential computer installations for several reasons: (1) Processes with product values greater than $5 million do not require a proportional number of control computers, e.g., a $20-million-a-year unit would need only one control computer, not four; (2) processes with product values under $5 million add to the industry's total sales and contribute to the estimate of 7,200 possible systems but would not ordinarily warrant an installation; and (3) to date, some processes—such as sulfuric acid—have not been found to possess the technical characteristics needed to justify a computer control system.

On the other hand. several arguments could be advanced for using a larger number: (1) The industry sales figure presumably reflects only intercompany transactions and ultimate consumer sales, overlooking intracompany transfers and multiple processing steps for many products which would mean a larger number of process units; and (2) smaller processes within a single plant could be grouped and controlled by a single computer.

On balance, a potential of 700 to 1,000 computer control systems for the chemical industry is probably realistic. On this basis, the chemical industry has installed computer control for 6 to 9 percent of the possible applications.

Companies supplying data on the employment effects of their process control computers had sales in 1964 of about $8 billion, thus representing approximately 22 percent of the industry. These companies account for almost two-thirds of the process computers in the chemical industry.

CHART 2. *Chemical*



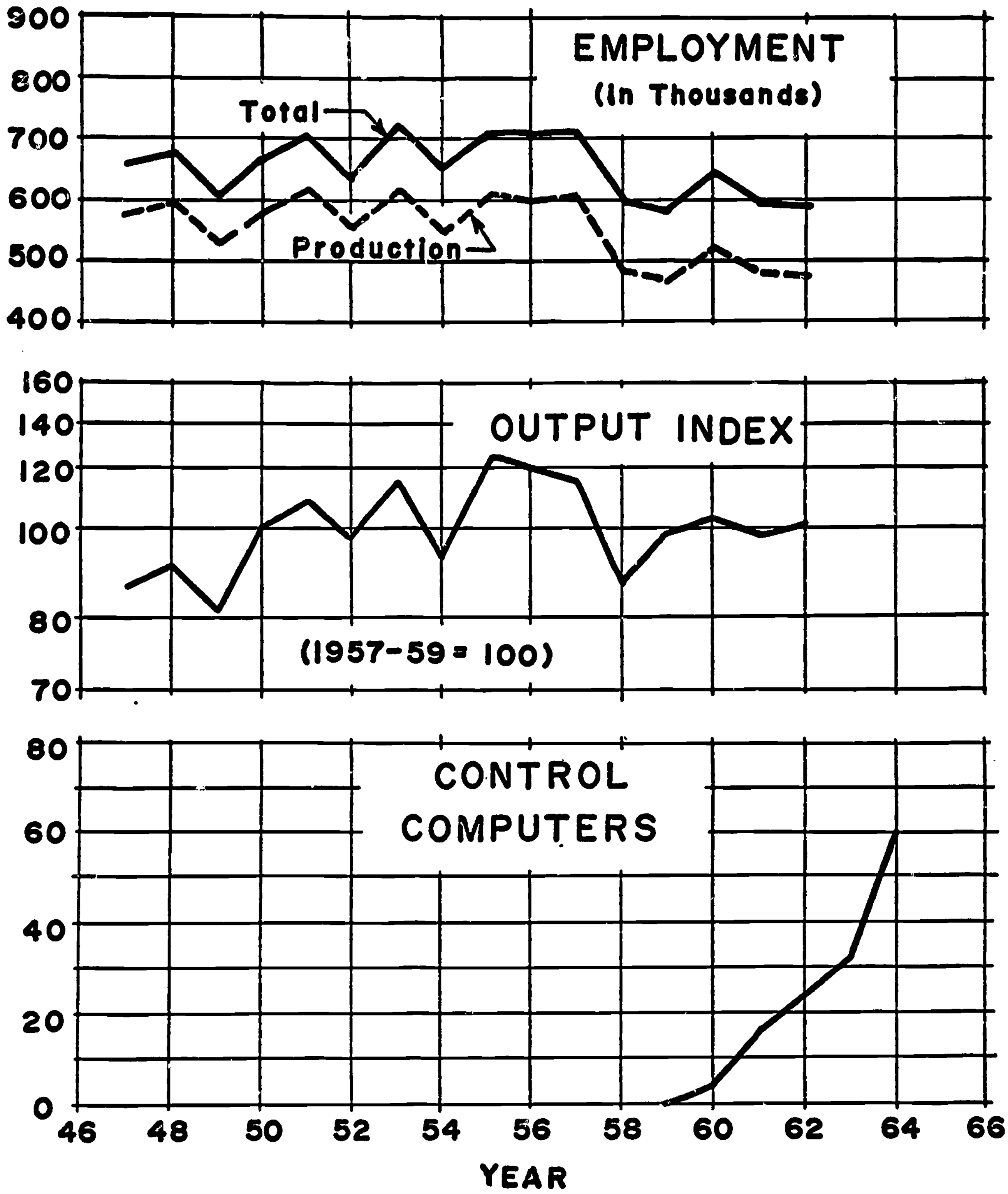
Iron and Steel

In the iron and steel industry, the level of production employment varies considerably but pretty well follows the production index. The gap between production and total employment is remaining quite constant or even growing somewhat. If there is a general trend in employment, it is downward from the high levels existing from 1951 to 1957. (See chart 3.)

Process computers were introduced about 1960, and about 60 are now installed or on order. From 1960 to 1962, the last year for which industry employment figures are on hand, production employment decreased approximately 50,000; in the same interval, about 22 process control computers were installed or ordered. These figures would indicate a displacement of 2,300 employees for each computer, far too many in view of experience and user testimony. At 4 employees per computer, a more reasonable figure, the 60 process computers would account for only 4×60=240 employees.

Changes in steel industry employment are explained by the introduction of such new processes as oxygen steelmaking and continuous casting. An oxygen furnace produces a heat of steel in 45 to 60 minutes, as compared to 4 to 6 hours or more for an open hearth furnace, and requires about the same size crew; as a result, both the plant investment and the labor cost for producing steel are

CHART 3. *Iron and Steel*

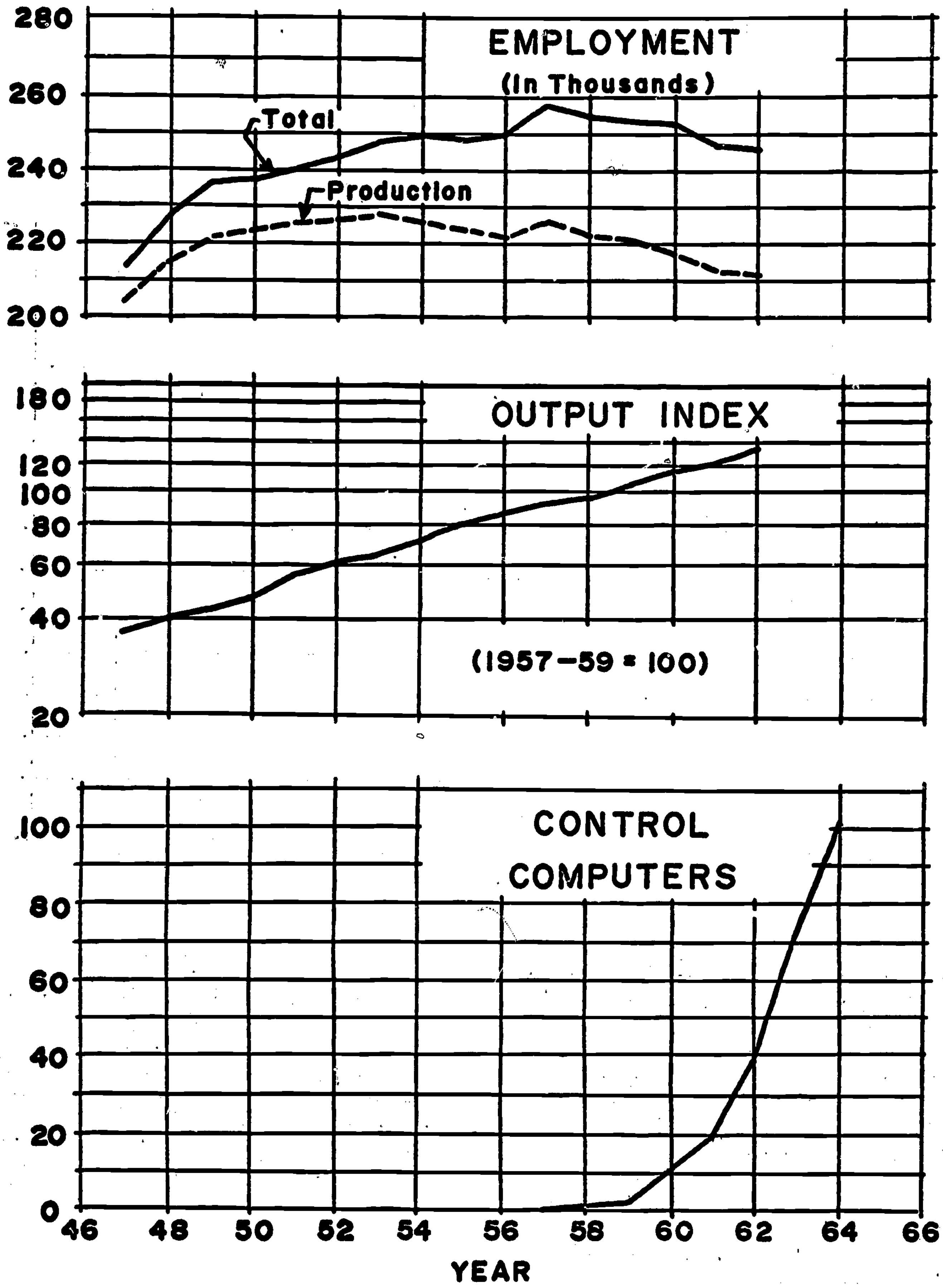


greatly reduced. Continuous casting permits molten steel to be converted directly into slabs or billets ready for rolling, thus eliminating the steps of pouring the steel into ingot molds, allowing the ingots to cool and solidify, removing the molds, reheating the ingots in soaking pits, and rolling the ingots into slabs or billets in a roughing mill; the savings in equipment, fuel, and labor are estimated at $8 to $10 per ton, a really significant part of the total production cost. It is no wonder these processes have caught the attention of steel producers.

As an indication of the employment impact of these new processes, *Business Week* (Aug. 14, 1965, p. 78) reported: "Last week, U.S. Steel Corp. announced it will shut down a 12-furnace open hearth shop at its Duquesne Works. Two recently installed oxygen furnaces will supply all the steel needs of the mill. Of the 250 displaced workers, U.S.S. says, only 20 to 30 who lack seniority for transfer, severance pay, or company-paid jobless benefits will be laid off. The remainder will be given early retirement or absorbed in other operations." *The Wall Street Journal* (Aug. 5, 1965) reported the same announcement, indicating that only 5 of the 12 open hearths were then operating and quoting a union official as saying, "the move will probably cause the layoff of about 125 men, with another 50 men either retiring or moving to other jobs."

The oxygen steelmaking facility at U.S. Steel's Duquesne Works has been equipped with a process control computer to collect data, make charge calculations, and exercise limited control functions. The computer is not essential to the operation; the furnaces must and can be run when the computer is not in service, and other steel companies (e.g., Kaiser, Colorado Fuel and Iron) run similar facilities without a process control computer. Clearly

CHART 4. *Electric Power*



it is the new process, not the control computer, that is responsible for employment changes.

Using a directory of steel mills and facilities, it was estimated that the steel industry could now use about 350 process control computers. On this basis, the steel industry has installed or ordered process control computers for about 17 percent of the potential applications.

The companies supplying data on the manpower effects of their process control computers have about half of the annual production capacity of the industry and slightly less than half of the process control computers installed or ordered to date.

Electric Power

The chart for the electric power industry (see chart 4) shows a very uniform growth rate for the output index. Production employment has declined from 1953 to 1962, from 228,000 down to 211,000; since 1957 there has even been a decline in the total employment.

The first computer was installed about 1958, and now the power industry has about 100 of them. About 40 had been installed or ordered by 1962, the last year for which employment figures are available. In the period 1958–62, production employment decreased by about 10,000, or 250 employees for each computer; as before, this figure is unreasonable. Assuming 1 shift position or 4 operating employees per computer, the total displacement through 1962 would be $4\times40=160$ or $4\times100=400$ through 1964, a small part of the total change in employment.

Growing productivity in the electric power industry is caused, in part, by use of larger generating units which can be manned by crews no bigger than before. The average unit size has grown from 80 mw. in 1955 to 200 mw. in 1965; in the same time period, the largest unit size has jumped from 300 mw. to more than 600 mw. For such large units, costs of an operator's misadjustment (which could increase fuel consumption) or serious mistake (which could cause damage requiring the unit to be shut down) are very high. The large size of the units is, in fact, an incentive for installation of control computers as a form of insurance against major catastrophes.

Taking the present generating capacity as 200,000 mw. for the United States as a whole and 300 mw. as the average size of the units for which control computers have been installed, one can estimate that the industry has automated $300\times100\div200{,}000=0.15$ or 15 percent of the total capacity. On this basis, the electric power industry can be expected eventually to have 600 to 700 control computers.

The three companies supplying data on employment effects of their computers represent only about 8 percent of the total number of control computers installed or ordered.

Pulp and Paper

Employment in the pulp and paper industry has been relatively constant since 1955, total employment having remained between 220,000 and 230,000, and production employment between 180,000 and 190,000. At the same time, output has been rising steadily. (See chart 5.)

Paper machines are now being built which produce wider sheets at higher speeds than ever before, thus providing more tons per hour, day, or year with little change in crew size. Continuous digesters are being installed in increasing numbers to produce better pulp more efficiently and with less labor. For example, one company studied modernization of its pulping facilities and reported (*Paper Trade Journal*, May 10, 1963) that a continuous digester with one operator would produce as much pulp as eight batch digesters with five operators; this company did not suggest use of a process control computer, although other companies are installing them for continuous digesters.

Process control computer utilization in the pulp and paper industry is in its infancy. The first systems were installed or ordered in 1961, and two of the earliest installations (Potlatch and Fitchburg) have since been removed. About 16 systems had been ordered through the end of 1964, with only 4 or 5 complete enough to be producing any results.

Many papermills are small and probably cannot justify installation of a process control computer. Nevertheless, there are probably 150 mills in the United States big enough to use at least 1 computer, and the largest mills can use 2 or 3 effectively, so the total potential is perhaps 300 to 400 installations. On this basis, the pulp and paper industry has only installed process control computers for 4 to 5 percent of the potential applications.

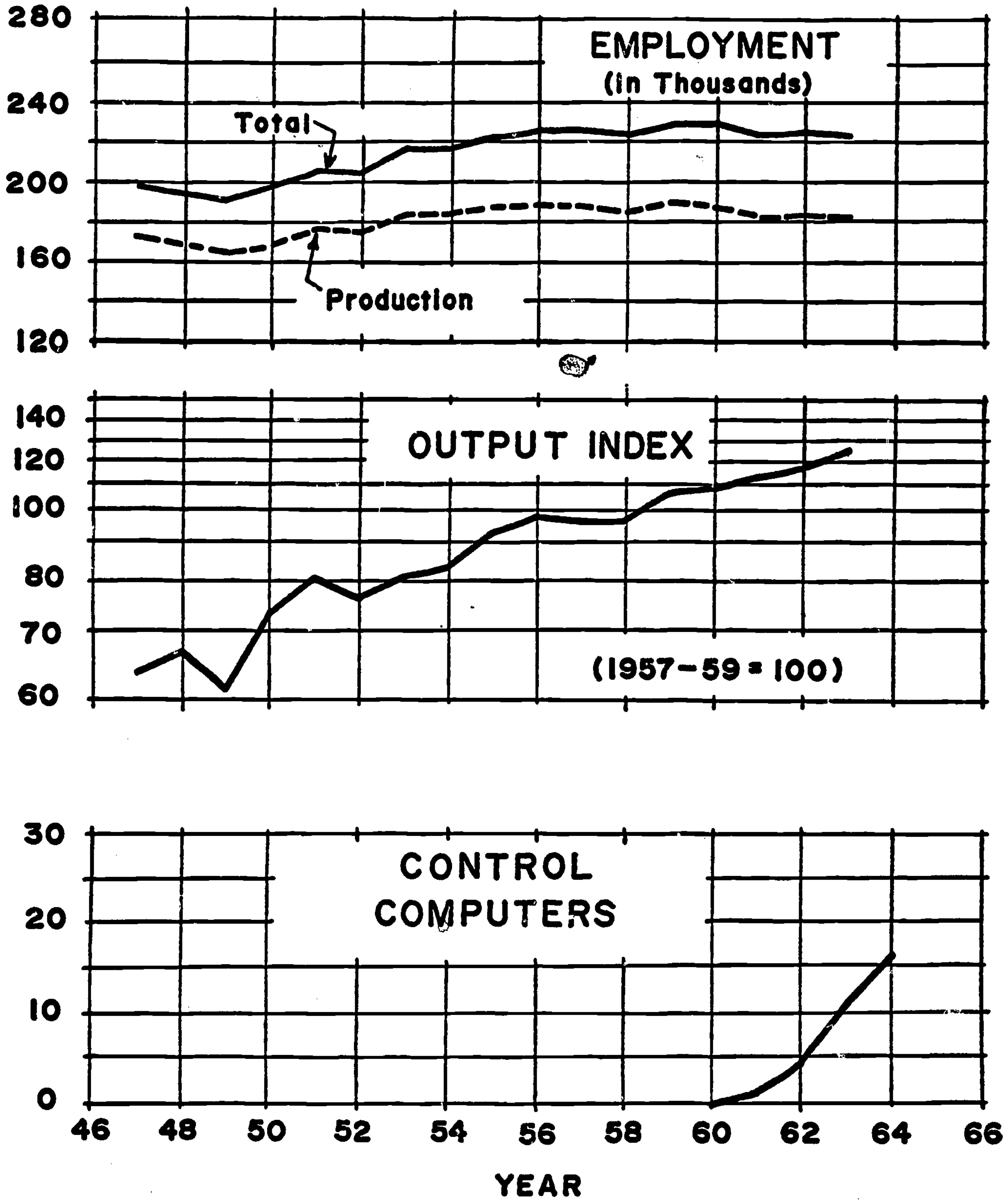
Cement

Employment in the cement industry, both total and production, has been dropping steadily from the high levels of 1956–58; total employment decreased from 44,400 in 1958 to 38,700 in 1964, while production employment in the same period decreased from 36,700 to 30,300. (See chart 6.)

Although it had a reputation as a "backward" industry, the cement industry's first computer installation was made in 1959, about the same time that pioneering installations were being made in electric power, petroleum, and chemical plants. About 14 process control computers had been installed or ordered by the end of 1964.

From a cement industry directory, it has been found that 130 plants in the United States produce

CHART 5. *Pulp and Paper*

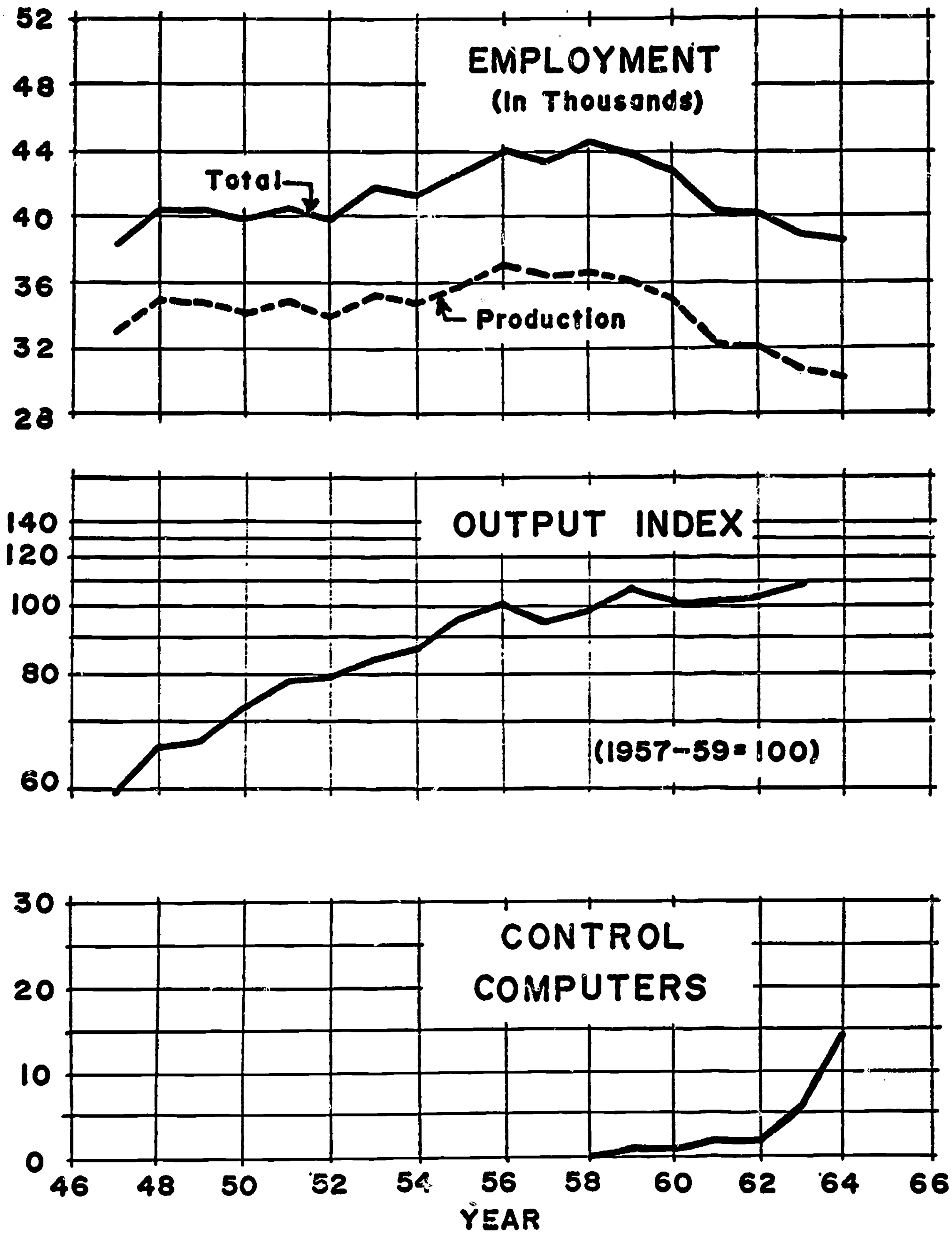


1,750,000 barrels of cement or more per year. At $3 per barrel, a typical price, these plants have an annual product value sufficient to justify consideration of computer control. If other technical criteria are also satisfied, this number—130—represents the approximate potential for process computer installations. On this basis, the cement industry has installed or ordered process control computers for about 10 percent of the possible applications.

As in several other process industries, larger equipment is a key factor in downward employment trends. Several companies have large kilns, 500 to 600 feet long with an annual production of 3 to 5 million barrels, installed in new plants or as replacements for old kilns which were 150 to 200 feet long and produced about 300,000 barrels per year. Grinding mills, the other major item of equipment in cement plants, have also been getting larger. The larger units offer savings in both operating and maintenance manpower. Centralized control rooms in modern plants also contribute to lower employment.

To indicate the importance of these changes, one company modernized a plant by installing 2 new kilns in place of a number of old ones, 1 crusher in place of 3, 2 raw material grinding mills in place of 11, and 2 finished cement grinding mills in place of 20. Annual production capacity was increased by 30 percent. The number of operators decreased from 50 to 16; laborers, from 30 to 16; and maintenance men from 60 to 30; the number of supervisory people was also reduced. The company has installed a process control computer (not yet in full operation) in this plant but flatly states that it had no part in reducing employment and, in fact, has required the addition of one man.

CHART 6. *Cement*



4. Future Trends

In this section, a recapitulation of conclusions from earlier sections of the report is presented, and an attempt is made to predict future trends.

A. Recapitulation

From the material presented in the first three sections of the report, the following conclusions should be drawn:

(1) Use of digital computers for industrial process control is the latest step in a continuing evolution of control techniques.

(2) Introduced about 1958–59, the number of process control computers installed or ordered has increased about tenfold in the last 5 years, or 60 to 80 percent per year.

(3) Coming at a time when processes already employed automatic control devices in great numbers and operating crews were already fairly small, the process control computer per se could have and has had only a very small effect on the number of men employed to operate process plants.

(4) Where changes in operating manpower have occurred, they are due primarily to introduction of new processes, construction of larger units, or other innovations permitted by a variety of technological advances.

(5) As explained at some length in section 2, installation of a process control computer requires the work of several engineers and programers over a period of 1 to 2 years or more; this effort represents a considerable cost, and people qualified for this activity must be added to the technical staff of the user organization or created from those already employed.

(6) Managements have been justifying the installation of process control computers by improvements in production capacity, raw material utilization, safety, and control of quality, not by reductions in manpower.

Because the employment effects of automation in general and process computers in particular have been widely discussed and often misunderstood, perhaps a few additional remarks on the subject are appropriate.

As has been noted earlier, the cost of a process control computer system is usually in the range of $200,000 to $400,000. The cost of the computer itself is $50,000 to $150,000. On a lease basis, the computer costs perhaps $1,500 to $5,000 per month. Taking the labor cost of one position as $3,000 per month (four men at $500–$600 each, plus fringe benefits and overhead) or $36,000 per year, it is evident that elimination of one position would be enough to cover the lease payments for an average computer system. Additional reductions would be needed to balance the purchase price of new instruments, process and control room modifications, and other items not ordinarily leased, as well as the costs of engineering, programing, and so forth.

If managements have not used manpower reduction as a justification, it has not been for any lack of desire to do so. Each position eliminated is a saving of $25,000 to $40,000 per year. These savings are hard cash, readily observed in a financial statement, unlike the small changes in production capacity or efficiency which are difficult to measure and easily obscured by market changes and other effects. Manpower reduction has not been used to justify process computer installation, chiefly because it is too difficult to eliminate operators in plants which already make widespread use of automatic control devices.

The difficulties here do not arise to any extent from restrictions in union contracts, either, although they may have some influence. Many contracts contain a clause stating that crew size can only be changed as a result of a technological innovation. The process control computer would appear to qualify as a "technological innovation," but managements have not grasped this apparent opportunity to redefine crew sizes. The real difficulty is that the number of operators in a modern plant is already close to the practical minimum, based on requirements during startup, shutdown, upset, and emergency conditions. Reductions substantial enough to offset the total costs of process computer systems being impossible, benefits are sought in other areas.

Of course, plant managements have a direct and genuine interest in greater production, reduced waste, and better control of quality. Where large increases in capacity are needed, the only solution is to build a new plant. Insofar as added capacity is concerned, a process control computer allows only minor gains and, in effect, just postpones construction of new capacity, simultaneously postponing employment of people to man the new plants.

One of the leading figures in the field, Dr. T. J. Williams (then with Monsanto and now a professor of engineering at Purdue University) discussed the justification for process control computers in 1961:[3]

1. A return on total plant investment of at least 0.5 percent/year (before taxes) is probably possible on any process solely from monitoring and long-term economic optimizing abilities of the computer.

2. A check for process bottlenecks should be made if a systems study shows that return of greater than about 6 percent/year (before taxes) is possible. If such a return is possible, the plant was not well designed in the first place.

Experience indicates that 3 to 5 percent is a typical amount of improvement due to a process control computer. In some cases, as much as 10 to 12 percent has been noted, and 0.5 to 2 percent is occasionally sufficient—for very large processes—to justify installation of a computer system.

Laymen seem to experience difficulty in understanding the motives behind installation of process control computers and accepting the idea that manpower reduction is not a primary motivation. In part, this difficulty stems from an inevitable lack of familiarity with the technical and economic factors just summarized. However, it can also be traced to misinformation about the subject appearing in newspapers, magazines, and books. Two examples will perhaps serve to illustrate the point.

Several years ago, an article in *The Nation* (Dec. 17, 1960, pp. 467–470) contained the sentence "There is now an oil refinery in Texas which is completely controlled by a giant computer—and it does a much better job than the human operators whom it replaced." A letter to the editor, published 6 weeks later (Feb. 4, 1961), pointed out that the computer was connected only to a small unit within the refinery, that it improved operations only slightly, and that no operators had been replaced. Despite this correction, the author of the article testified before a U.S. Senate subcommittee in 1963, and offered a guess that the installation had replaced a half dozen men in the control room. The company in question admits to a recent reduction from three men per shift to 2½ (one man dividing his time between two units), or somewhat over two men in all.[4]

Automation: Industrialization Comes of Age by William Francois (Collier Books, New York, 1964) contains the following paragraph:

IBM was not the first computer manufacturer to market such controls. Monsanto Chemical Co., aided by Thompson-Ramo-Wooldridge Products Co., studied such a possibility in 1958. Two years later an RW-300 computer system was fully controlling an ammoniamaking process at Monsanto's plant in Luling, La. The decision to go ahead with the installation was based on greater reliability of computers and the expectation that production might be increased 75 percent as a result of refinements introduced by computer control.

A 75-percent increase in production would indeed be a striking inducement for installation of a process control computer! However, the author has misplaced a decimal point or suffered a typographical error: 7.5 percent would be much closer to the truth.

Before the computer was installed, Monsanto's Luling ammonia plant was rated at 450 tons per day, already substantially higher than the design capacity of 300 tons per day at the time of startup in 1954. After the number of gas compressors was increased from 6 to 7, about the time the computer system was being designed, the capacity went up to 525 tons per day. When the computer system was being connected in 1960, another compressor and a synthesis reactor were being installed, sufficient to raise the capacity another 75 tons per day to 600 tons per day. After the computer system had been operating a few months, Monsanto held an open house for the press and admitted that production had gone up "more than 1 percent." This history was fully reported in the trade press at the time (see, for example, *Chemical Engineering*, Nov. 14, 1960, pp. 110–114 and *Petroleum Week*, Nov. 14, 1960, p. 34).

A recent industrywide tabulation of ammonia plant capacities (*Chemical Week*, Sept. 11, 1965) showed Monsanto's Luling plant with an estimated capacity of 220,000 tons per year in 1964, almost exactly 600 tons per day on a 365-day-per-year basis and somewhat more if allowance is made for some downtime. The capacity at Luling is being doubled in 1965 with the addition of a complete, parallel ammonia plant, also 600 tons per day and also equipped with a process control computer.

Nowhere in these figures can one find a basis for attributing a 75 percent increase in capacity to the first control computer.

B. Future Trends

The effect of process control computers on operating manpower can be calculated from the following relationship:

$$\begin{matrix}\text{Total}\\\text{number}\\\text{displaced}\end{matrix} = \begin{pmatrix}\text{number}\\\text{of}\\\text{installations}\end{pmatrix}\begin{pmatrix}\text{men displaced}\\\text{per}\\\text{installation}\end{pmatrix}$$

The number of installations is known with reasonable precision, but the number of operators displaced per installation can only be guessed. In many instances, the number reported is zero. If this figure were universally applicable, the prediction of future employment effects would be easy.

[3] *Systems Engineering for the Process Industries*, McGraw-Hill Book Co., New York, 1961, p. 72.
[4] See *Fortune*, January 1965, pp. 124 et seq.; March 1965, pp. 74–80.

because the above calculation would become simply:

$$\begin{matrix}\text{Total}\\ \text{number}=\\ \text{displaced}\end{matrix}\left(\begin{matrix}\text{number}\\ \text{of}\\ \text{installations}\end{matrix}\right)\left(\text{zero}\right)=0$$

The expected number of installations is immaterial, and predictions of the extent of process computer utilization in the future are not even necessary.

Reports from users quoted in section 3 suggest that an average displacement of one operator per computer system may be closer to the mark. If so, the computers installed or ordered through 1964 would cause a total displacement of about 300 operators.

Being somewhat more generous and taking one shift position or four operators per computer system as the average effect on employment, total operator displacement to date and expected in the future would be as shown in table 3. This table includes figures from section 3 on the number of potential installations in the six industries which have been the principal users of process computers; together, they account for 90 percent of the systems installed or ordered through 1964. Their total potential is 2,300 to 2,800 computer systems. These industries have now installed or ordered process computer systems for 10 to 12 percent of their potential applications.

Assuming—repeat, assuming—4 operators per computer system, total operator displacement through 1964 in these 6 industries would be about 1,100 men, and the ultimate displacement would be on the order of 9,000 to 11,000 men. If these industries continued to have 90 percent of the potential installations, allowing for other industries would raise the total to 10,000 to 12,000 men. However, other users—such as pipelines, nonferrous metals, glass, foods, and textiles—which got a later start in the field may become more active and may eventually account for appreciably more than 10 percent of the total number of process computer installations. If their share increased to 50 percent, the total operator displacement would reach only about 20,000 men.

TABLE 3. PROCESS COMPUTERS INSTALLATIONS, THROUGH 1964 AND POTENTIAL, AND THEIR EFFECT ON OPERATING MANPOWER

Industry	Process computer installations			Reduction in operating manpower (assuming four men per computer)	
	Through 1964	Potential	Through 1964 as percent of potential	Through 1964	Potential
Chemical	58	700–1,000	6–9	240	2,800–4,000
Steel	61	350	17	240	1,400
Electric power	101	600–700	15	400	2,400–2,800
Petroleum	27	250	10	110	1,000
Cement	14	130	10	55	520
Pulp and paper	16	300–400	4–5	65	1,200–1,600
Total	277	2,330–2,830	10–12	1,110	9,320–11,320

These calculations do not attempt to predict the number of additional people who must be employed to plan, design, program, install, and maintain the computer systems. Some of these people are employed by instrument and computer vendors. No figures are published, of course, but the present total—not counting people involved in computer manufacture or in the other activities of the vendor companies—may be on the order of 800. Based on 2 or 3 men employed by the users for each system being installed, another 600 to 1,000 people are occupied with process computer work in the user organizations. (Some of these are new additions to their staffs, and others have been reassigned from other positions.) The number of new positions created by the process control computer equals or exceeds the number of operating people displaced.

To be sure, positions concerned with planning, designing, programing, and installing process control computers demand skills and training well beyond those of the normal operator. People in these positions generally have one or more degrees in engineering, mathematics, chemistry, physics, or other sciences, as well as some industrial experience. The academic training provides the knowledge needed to develop process models and control schemes, while the industrial experience furnishes a sense of proportion and judgment about suitable objectives for a process control computer. Universities are attempting to supply graduates with the requisite training but are handicapped by a shortage of qualified faculty and facilities to fill the gap; user companies have conducted their own training courses, sent their employees to vendor- and university-sponsored short courses, and thrown people into projects for on-the-job training.

The rate of process computer utilization is limited in part by management hesitancy to move ahead without a convincing justification, often difficult to supply, and by a shortage of people able to install the systems. Even if management suddenly dropped all financial barriers, the number of installations per month could not be greatly increased because the necessary engineering and scientific manpower is not available and cannot be developed overnight. Thus, the possible displacement of operating manpower will take place gradually, over a period of years, at a rate which minimizes the impact on total industry employment.

These predictions have implicitly assumed no radical changes in the ways that process computers are used to cause significant increases in either the number of potential installations or the employment effect per installation. Such changes, if they do occur, will also be gradual. A few pioneers will lead the way, and others will straggle along after them. Two extensions to the original computer control concepts have already appeared and are being tried experimentally in a few plants.

One concept receiving much attention these days is direct digital control (DDC). As explained at the end of section 1, this technique consists of using a single digital computer to exercise control in sequence over a large number of process conditions, replacing an equivalent number of conventional controllers. DDC performs no new functions and is justified on a straight comparison of equipment, engineering, and maintenance costs, with some credit for data processing and logging which can be done at slight additional expense. DDC will probably find its greatest acceptance in new plants, where no existing control equipment will have to be scrapped. If widely adopted, DDC will increase the number of process control computers and will increase manpower needed for equipment installation without causing any associated labor displacement. No operating people are displaced by DDC, per se, unless it plays an essential role in consolidation of control rooms previously separated by distances too great for coupling by conventional analog methods.

Multiunit control, in which a single computer exercises control over several processes within a plant, is another concept now receiving consideration. If used only for supervisory control (that is, to determine the best operating conditions considering the links between processes as well as their internal relationships), with local controllers and control rooms preserved for regulation functions within each process, the multiunit control computer will have little effect on operating manpower levels.

Elimination of the local controllers and control rooms, with a central computer performing DDC and supervisory control functions for a whole plant, would have noticeable effects on operating manpower requirements. A plant could be run by a crew of the size now found in any one of the control rooms, aided by men roving the plant to spot troubles and perform maintenance. However, use of multiunit control of this nature is hampered by operational problems of starting up and shutting down processes at long range, as well as concern about "putting all the eggs in one basket." Computer reliability is being improved continuously, but provisions for automatic or remote startup and shutdown are likely to be quite expensive in relation to the benefits achieved.

All things considered, the process industries have a 10-year task ahead of them in absorbing and taking advantage of control techniques now available. The manpower implications of these techniques are dwarfed by the impact of technological changes in the processes themselves.

AUTOMATION IN THE FABRICATING INDUSTRIES

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CONTENTS

Automation in the Fabricating Industries

Introduction

Ten years ago in a study of automation and technological change, the Subcommittee on Economic Stabilization of the Joint Committee on the Economic Report stated, "We are clearly on the threshold of an industrial age, the significance of which we cannot predict and with potentialities which we cannot fully appreciate." Within the past 10 years it has become increasingly clear that the technological changes brought about by automation are of great significance, although their import is not yet fully known. Whereas their potentialities, in a technological sense, are better recognized, the economic and social consequences of automation are still the subject of debate. On the one hand, the concept of the automatic factory has given rise to the specter of the workless society; on the other hand, there are those who insist that "the more things change, the more they remain the same," and that automation is merely one additional step on the rung of technical progress and is not a far-reaching revolution.

Automation has many faces and takes on different forms in the various manufacturing processes. Its contribution to productivity is often merged in the gradual progressive changes taking place in manufacturing methods and equipment. Its productive potential varies with the application. Its labor displacing impact arises from many diverse developments. Changes in manufacturing methods and occupational skills can already be noted in industries where automation has been introduced, for automation is a complex process in which men, machines, and products are interrelated. Automation results in the transformation of human tasks and the qualifications required for those tasks. Automation requires the development of new machines, controls, and manufacturing processes. Automation calls for new methods of product design and management control.

The complex process of automation is developing in an economy which employed more than 70 million workers in 1965 and which will require employment for 87 million by 1975. More than 100,000 factories and other work establishments, each of which employed more than 20 workers, utilized several million machines in 1965.

To scale the problem realistically, this study is intended to focus on a microcosm of the total picture and to investigate two particular automation processes and their effects in a selected group of industries. The automation processes are numerical control and automatic assembly. The group of industries are six manufacturing industries of durable goods, referred to as the fabricating industries.

The fabricating industries are those which make components, usually by machining or forming, and assemble them into finished products. The six industries include:

1. Fabricated metal products;
2. Machinery (except electrical);
3. Electrical machinery;
4. Transportation equipment;
5. Instruments and related products;
6. Miscellaneous manufacturing industries.

Ordnance (SIC 19) is sometimes considered with the fabricating industries; it is often grouped under miscellaneous manufacturing industries. A more detailed breakdown of these industries as listed in the Standard Industrial Classification Manual [1] is shown in appendix A.

The 30,481 plants with 20 or more employees in the six fabricating industries comprised 30.3 percent of the total number of manufacturing plants in the U.S. (1963 figures). These plants employed 6.7 million workers in 1964, comprising 9.6 percent of the total number of employed workers and 30.8 percent of the total number of craftsmen and operatives.

The two automation technologies under review are highly differeniated, are in different stages of development, and have different areas of application. In the context of the total manufacturing process, however, these two technologies are complementary. In their economic and social implications, they are twins.

Numerical control is a technique for automatic machining which has emerged from a fusion of the computer, control, and machinery technologies. Machining or fabrication is accomplished by a programed sequence of instructions in a numerical (digital) form which are interpreted by a controller device that directs a machine to perform the desired operations without inter-

[1] *Standard Industrial Classification Manual,* Bureau of the Budget, Washington, D.C., 1957.

vening human decisions. The digital instructions may be entered on dials or plugboards or be recorded on punched cards, punched paper tape, or magnetic tape. The operations may be a sequence of discrete tasks such as drilling holes at designated locations or a continuous operation such as milling a complex metal part. Control may be over two axes or may extend to as many as six axes.

Developed in the years preceding 1953 and introduced commercially in 1954, numerically controlled machines have now begun to diffuse throughout industry. The number of machines in use is growing rapidly and the investment in these machines is accelerating.

Automatic assembly lacks rigorous definition and many plants using automatic techniques do not consider themselves as assembling a product automatically. For purposes of this report, automatic assembly is defined as any operation in which two or more parts are oriented in relationship to one another so that they can be mated or assembled and often physically fastened together, without human intervention. The parts are frequently referred to in industry as piece parts but they could also be subassemblies composed of piece parts. This distinction of parts is made to preclude confusion with the parts that may be considered to make up a package. Automatic packaging is not discussed in this report. Automatic assembly includes the assembly of balls and races to make ball bearing assemblies, gears and levers to make clocks, or engine parts to make automobile engines.

Automatic assembly has been used for years in the manufacture of light bulbs, radio tubes, tin cans, and some safety razors. The automobile industry achieved some automatic assembly on internal mechanisms and subassemblies several years ago. Automatic assembly, on what must still be considered a very small scale, did not appear until the early 1950's. Early operating difficulties with automatic assembly installations retarded much further growth until the early 1960's. Since this period, the number of automatic assembly installations has increased but growth is still slow.

Numerical control is highly adapted for use with computers which provide a large measure of flexibility. Special-purpose hardware can often be replaced by software (programing). From an economic viewpoint, numerical control is used to best advantage in small lot production, 10 to 50 pieces.

Automatic assembly, on the other hand, is economically feasible in the mass production industries where volume is one-half to 1 million assemblies per year. It is still largely in the mechanical stage; machines are highly specialized and, therefore, inflexible. Except for isolated applications, as for example, wire wrapping and specialized electronic fabrication, the assembly process is not under computer control.

The technological and economic implications of these two technologies are reviewed in this two-part report: Automation in the Fabricating Industries, part 1. Status and Potential of Numerical Control; part 2. Status and Potential of Automatic Assembly.

An estimate of the extent of the growth and diffusion of numerically controlled and automatic assembly machines in the fabricating industries is made in this report. The implications of these technologies during the next decade are also assessed in relation to fabricating processes, employment, and skills. Specifically, guidelines are sought for evaluating the following areas:

1. The characteristics of computer control in the fabricating industries in regard to numerical control and automatic assembly.
2. The extent of the spread of these technologies in the fabricating industries.
3. Their possible rates of penetration in the decade 1965–75.
4. The present and future effects of present and impending technological developments on employment by industry and occupation.
5. The effects of these technologies on job content and skill requirements.

Because the technological developments described in this report are taking place in a dynamic society, their effects are responsive to many complex factors not directly associated with the technology. Population growth and changes in the age distribution, the state of the economy, structural changes in the economy, and the problem of war or peace will weigh heavily upon the impact of numerical control and automatic assembly in the areas cited above. It is the aim of this report, therefore, to establish data for assessing the effects of these technologies in the fabricating industries. Given these data and assumptions concerning socioeconomic developments during the next decade, their implications on total employment, working conditions, earnings, job satisfaction, labor market, collective bargaining, and economic institutions can be better understood within the context of the whole economy. A socioeconomic policy designed to modulate the adverse effects of automation and extend the positive achievements may then be formulated.

PART 1: STATUS AND POTENTIAL OF NUMERICAL CONTROL

1. Summary and Conclusions

Numerical Control Technology

Numerical control (NC) in its strict sense is a technique for machining. In a larger sense, numerical control is a concept of a total manufacturing process in which design, fabrication, testing, scheduling, and management are closely interrelated. New loci of decisionmaking are being evolved and methods of information generation and transformation are undergoing change. The growing awareness of this wider concept of numerical control has the most significant implications for industry. Occupational skills will be greatly affected, as will employment. The impact of the numerical control process in the future will pass beyond the machining industry and permeate into many other areas of manufacturing technology.

Because numerical control is but one facet of a many-faceted and dynamically changing technology, its specific effects cannot be readily measured. It is one area of advance in the general field of automation. Its development is taking place concurrently with important changes in the raw materials, the machines, and competitive processes and materials of industry. Further, technological developments are taking place in a complex society and their effects are responsive to many factors not directly associated with the technology.

NC is a new and important contributor to the increasing productivity of machine tools that has been evident over the years. It is generally estimated that NC offers a fourfold increase in production for a twofold increase in machine cost. Machining time is only 20 to 30 percent of that required for conventional machining; tooling costs can be 70 to 80 percent lower; scheduling can be more accurate since accurate estimates of machine time can be obtained during computer preparation of the control tapes. In addition, errors are reduced, repeatability is assured, and accuracy is enhanced. Resulting inspection, quality control, and assembly costs are thereby reduced.

The increased production of NC machines is reducing their cost, and technological development is increasing their production capactiy. Inasmuch as NC machine tool makers are themselves increasingly turning to the use of NC machines, this process has a compounding effect.

First Decade Growth, 1954–64

Numerical control is entering its second decade. The first decade, 1954–64, saw the beginning of the commercial use of NC machine tools and a growth in the NC machine inventory to 5,100 machines with a value of $384 million. Nearly 75 percent of this growth has occurred in the 3-year period, 1962–64. More than 6,000 NC machines were in use by mid-1965 and it is estimated that over 10,000 will be in use by the end of 1966.

In a period of 6 years the annual investment in NC machines has jumped over 600 percent from $17.3 million in 1959 to $105.5 million in 1964. The expected expenditure of $318 million on NC machines in the next 18-month period represents 82.8 percent of the cumulative expenditure in the period 1954–64.

The average increase in the value of NC machines as a percent of the annual value of shipped metal cutting machines was 1.86 percent during the period 1959–63. In 1964, the percentage was around 12 and has been estimated at 17 in 1965. Purchase estimates for the next 18 months suggest this figure will rise to over 22 percent. The aerospace industry estimates that 61 percent of their investment in metal cutting machines will be for NC in 1965–66. The $60 million planned investment by machine tool makers in NC machines represents 42 percent of their metal cutting purchases.

Although the growth figures are impressive in an absolute sense, it is necessary to evaluate them against the background of total machine production and total capital spending for a realistic picture of the extent of NC diffusion. In 1964, NC machines made up less than 1 percent of the total number of metalworking machines shipped. Excluding machines with an average value of less than $1,000 and all metal forming machines, NC machines comprised 2.5 percent of the remainder. Considering capital expenditures of the fabricating industries for new machines and equipment, NC machine value increased over 300 percent between 1959 and 1962 but was only 2.8 percent of the capital investment in the latter year.

The number of plants in the six fabricating industries having NC machines is estimated at between 2 to 4 percent. In relation to the more than 2 million metalworking machines in use in all manufacturing plants, about one-quarter of 1 percent of machines are NC.

Diffusion in Industry

The Takeoff Stage. Two techniques were used to assess the absolute growth figures of NC machines in relation to their diffusion potential. One method was to develop a model of technological diffusion and to identify the status of the NC technology in regard to the model. The second technique was to list diffusion constraints and to estimate their restraining effects upon the widespread and rapid diffusion of the NC technology.

The diffusion of a technology in industry is a four-stage process. The first stage is the pretechnology or traditional stage of industry during which the new technology is developed within the framework of the old. The second stage is one of transition; prototype models leave the laboratory and are established as a product line with a range of sizes and prices for an expanding number of applications. The third is the takeoff stage during which a rapid diffusion of the technology takes place. The stage of maturity completes the diffusion process; the new technology becomes widely diffused and becomes a standard part of the traditional.

For NC, the stage of pretechnology may be said to have ended by 1958. The period 1959–65 characterized the transition period during which NC found its way into an expanding number of manufacturing plants; a greater number of applications were found, and knowledge as to the potential of NC as a manufacturing process took root. The period beginning in 1966 will be the start of the takeoff stage and increasing growth and diffusion can be expected.

Factors which provide a basis for the takeoff stage include:

1. A wide variety of NC machines for diverse applications at prices customers can pay.
2. Expansion of the computer technology and its support role.
3. Simplification of NC programing by the widespread use of APT (Automatically Programed Tools) and other related languages.
4. Availability of other NC services: production centers, computer service bureaus, and data communications.

Diffusion Constraints. The rate of diffusion is dependent upon the aggregate of decisions which plants make in accordance with the following criteria:

1. Is the technology amenable to the unique circumstances of the individual plant?
2. Is the technology economically feasible; that is, will it result in reduced costs and increased productivity?
3. Can the capital investment required for equipment, retraining, and maintenance be justified and obtained?

Operating in the context of the general economic situation, plants will be influenced in their decisions by diffusion constraints. These constraints are factors which will tend to restrain the growing use of NC machines and impede their expansion into all areas of the fabricating industries. These constraints appear in the machine tool industry, the user community, and the worker community.

The machine tool industry is a fragmented industry with many little companies surrounding a few giants. Research investment is meager and manufacturing methods are traditional with small-run, custom jobs highly oriented to individual customers.

The diffusion of NC among the 87,000 manufacturing plants in the six fabricating industries and the 14,500 machine shops and 7,000 tool and die shops is dependent upon the amenability of the manufacturing process to NC techniques and the economic feasibility of NC conversion. Economic feasibility is not determined primarily by the size of the plant but by the nature of the plant's production.

NC has its greatest economic potential in small-lot size production where tooling, setup, and machining costs are high. With tape control replacing fixtures, the cost of small runs is reduced. NC may be more economical for even one or two complex pieces that require contour machining.

The lead time required to obtain NC machines, install them in plants, and train personnel to operate, program, and maintain them will serve to spread the diffusion of NC over a period of time. Another critical constraint is obsolescence of the manufacturing equipment and the huge amount of capital that will be required to modernize. With 64 percent of metalworking machines 10 or more years old and an obsolescent plant capacity which has been estimated at $95 billion, it will take many years for industry to renovate its plant even with the best of intentions.

The social and economic implications of NC as a part of automation confront the workers and the unions with a difficult situation. The struggle over worker satisfaction, occupational status, changing skill requirements, and seniority will serve as constraints in a social system in which economic values must compete with other values in the allocation of resources.

The future growth and diffusion of the NC technology are dependent upon other factors which are difficult to assess. These are the annual production of metalworking machinery which is highly variable, new applications for NC, and the changing machine mix brought about by changes in materials and processes.

NC machines have already been introduced into nonmetalworking operations such as welding, filament winding, flame cutting, wiring, and drafting. Future expansion is seen into new areas including microfabrication, microassembly, and optics. Some fabricating, transfer, and assembly operations will also become amenable to NC.

The expanded use of hardened metals and exotic metals and the competition of plastics and new alloys will effect changes in machining requirements and costs. New methods for removing metal include electrical discharge machining, electrochemical milling, chemical milling, sonic abrasion, chlorine machining, electron beam, plasma arc, and laser beams. Although most of these new processes are presently applied to situations where normal metal cutting is not feasible, a trend to more diverse commercial applications has begun.

Competitive methods for shaping parts, most of which are amenable to automation and numerical control, will affect the need for machining. A long range projection of Air Force equipment requirements, for example, indicates a shift from machining to forming and joining processes. A 50 percent decrease in the 1975 machine inventory was projected at a cost 50 percent greater than that of the 1964 inventory. A nearly 80 percent decrease in the 28,500 material-removing machines is foreseen, although the value of the nearly 6,000 machines of 1975 vintage is expected to be nearly the same as the total of their predecessors.

In general, it is estimated that conventional machining methods will decrease from 5 to 20 percent under the pressure of competitive methods and that relative manpower requirements will decrease by from 20 to 60 percent. The latter estimate does not include further reductions arising from numerical control techniques.

Because the protection of NC growth and diffusion is dependent upon the many complex variables summarized above, it is believed that a quantitative estimate will not be meaningful. The number of NC machines will grow, more and more industries will utilize these machines, and more establishments will discover other processes which can be numerically controlled. The growth will be constrained by many strong inertial forces and the large capital expenditures that will be required.

Employment Implications

The Outlook. Because NC machines will replace conventional machines and will be built by the same industry, a new NC industry is not foreseen. The total number of machines being produced will decrease as the NC takeoff gets under way because of a 3:1 to 8:1 displacement ratio. The NC machine builders themselves will increasingly turn to NC machines to cut costs of their production. As a result, the number of workers required to produce fewer machines with more automatic equipment will tend to decrease.

Increased requirements for auxiliary control devices and equipment will generate more demand which can be translated into some employment growth, subject to productivity increases within the relevant industries. A distinctive rise in computer demand stemming from NC requirements is not anticipated.

Among the user community, the number of workers directly employed on NC machines will decrease because of the machine displacement ratio and because one operator can often tend more than one NC machine. The greater design freedom afforded by NC methods and the greater accuracy and reliability that can be achieved will also tend to reduce the number of workers required for assembly, testing, inspection, and quality control. Maintenance personnel required to service complex NC machines may not be greater in number than that presently required. Requirements for draftsmen will decline as computer-aided design techniques and automatic drafting machines gradually take over many of the draftsman's functions.

It is doubted that the slack arising from displacement of production workers will be taken up by part programers. The output of a programer is increasing due to increasing sophistication of NC programing languages. The increasing availability of computer manufacture programing assistance and service centers will also serve to restrain the growth of large NC programer staffs. More critical in this respect is the forthcoming use of computer-aided design which may, in large measure, bypass the part programer and directly produce an NC tape from an internally stored design placed in a computer by a design engineer drawing lines on the screen of a graphics console.

The economic competition generated by the full utilization of NC technology will have its effect upon the small and inefficient machine shop, tool and die shop, and manufacturing plant. Larger firms will look closely at plant consolidation for purposes of economy and better utilization of resources.

Most directly affected by the NC technology will be the 1,100,000 workers presently employed as machine tool operators, machinists, layout men, tool and die makers, and setup men. Especially vulnerable are workers in these occupations who are employed in defense-related industries. These skilled workers and operatives are employed in facilities almost wholly built for the production of specialized equipment. Because the machines and processes in the defense-related industries are the result of heavily funded research and development, NC technology will have major impact on these industries, and their workers will face unemployment in shifts from defense spending and disemployment from the adoption of new technologies.

Employment Review. The cumulative effects of automation in the fabricating industries in which NC technology has only begun to have an effect can be glimpsed from an economic review of the period 1950–64. This period has coincided with the advent of the automation era and includes the maturation stage of computer technology and the transition stage of NC technology.

The average annual increase in the index of output per man-hour, one measure of productivity, was 2.5 percent during this period: 1.8 percent from 1950–54, 2.5 percent from 1955–59, 3.1 percent from 1960–64.

The number of craftsmen in all industry increased by 1.3 million in the 15-year period beginning in 1950, while their percent of total employment decreased very little. The number of operatives fell from 20.3 to 18.4 percent of total employment although increasing 0.7 million. Unemployment rates for craftsmen have consistently been lower than the rates for all occupations; semiskilled operative unemployment has been consistently higher than for all occupations and 30 to 60 percent higher than for craftsmen.

In the six fabricating industries during the period 1955–64, the first decade of NC technology, total employment increased by only 361,000 workers. The increase, however, was in the category of nonproduction workers which grew by 459,000 employees; production workers decreased by 100,000. During this period, the ratio of nonproduction workers in the six industries rose from 23.8 percent of total employees to 29.3 percent, a rise of 23 percent in 10 years.

During this same period, GNP rose from $397.5 billion to $622.3 billion (values in current dollars), and total employment rose from 63 million to more than 70 million. During the period 1955–62, the six fabricating industries increased their contribution to the GNP from $67.9 billion to $74.1 billion (1954 dollars) with an increase of only 95,000 workers. Thus a large expansion in the general economy was required for the number of workers in the fabricating industries to remain relatively stable.

The growing diffusion of NC technology will further affect the employment picture. Although some disemployment will be compensated for by the approximately 25,000 replacements required annually for retirements and deaths, and some workers will be absorbed by retraining and occupational shifts, the key problem is employment growth rather than stability through attrition. By itself, NC technology does not appear to hold promise to generate employment and will tend, in the long run, to diminish the number of employed. As the number of NC machines grows and their use becomes more widely diffused, the rate of disemployment will increase.

An expanding economy will not necessarily be employment-creating in the industries amenable to NC technology. One of the motivations for introduction of NC, besides labor savings, is decreasing the cost of production by more intensive and rationalized manufacturing methods. Hence an expanding economy with an increasing product demand will itself generate pressures to install NC machines with their labor saving potential.

Skill Requirements and Occupational Shifts

The number of workers required by the NC technology will not only be smaller than the number required by conventional techniques; it will be a different work force with new skill requirements. There will be an increasing need for highly trained specialists: designers, engineers, computer programers, tooling planners, production schedulers, electronics and servomechanism-oriented maintenance men. Highly trained machinists will not be required to operate the machines under control of a tape prepared by the specialists. Hence, there will be a downgrading of this skill. Some machinists will be retrained to join the team of specialists, especially in the role of part programers.

Computer-aided design through the use of graphics consoles and computers has the potential to diminish the role of the part programer. In connection with automatic drafting machines, computer-aided design and NC programing will diminish the role of the draftsman.

2. Numerical Control Technology

Information and Decisionmaking

Numerical control offers a means of controlling a manufacturing process in which technological sophistication in machines is combined with the imaginative skills of man. The earliest demonstration of numerical control in the U.S. was achieved in 1952 at what is now the Lincoln Laboratories of the Massachusetts Institute of Technology. The accomplishment consisted of directing a machine tool to move to a series of discrete positions when given numeric commands. Although the positioning accuracy of the system was relatively low, the demonstration proved that the process was feasible.

Subsequent development of numerical control technology has made it possible to machine complex shapes to close tolerances, achieve repeatability from part-to-part, and reduce machining time by a large factor.

The major elements of a numerical control system are the controller and the machine tool. The controller provides direct control of the machine tool which, in conventional machining, is under control of a man's hands. Man is removed one step from physically directing the tool.

The controller accepts a numeric description of the desired motions of the machine tool and converts the numeric commands into signals, which control motors attached to lead screws, which in turn move the machine tool bed, or spindle, or both. In a conventional machine tool, the signals and the motor movements are supplied by a human operator.

Where numerical control is used for machining, a basic change in the decisionmaking procedure is taking place. Very few decisions relating to the machining environment remain after the control tape has been prepared. The selection of machining speeds and the sequence of operations are now determined by the designer and the part programer; in conventional machining, these decisions were almost exclusively the responsibility of a skilled machinist. Information generation in the numerical controlled machining process is thus changed, with the blueprint no longer the respository of a part definition which a machinist transforms into a physical object. The computer is used extensively for both the generation of the definition and the transformation of the definition into the detailed commands on the control tape.

A part programer develops an abstract concept of the part to be machined and, using special languages, defines the desired set of motions to the computer. The designer is no longer constrained by the limitations of human machinists and can pursue solutions to design problems relating more directly to the intended function of the part to be manufactured. Designs once impractical due to the limits of time and money are now becoming practical.

The repetitious tasks of machining are performed automatically. The human operator monitors machine performance and is responsible for shutdown if the need should arise. He is responsible for the accurate positioning of the workpiece relative to the machine and for gross inspection of the finished part.

Machines, however, cannot make judgments. They do not adjust to new conditions nor critically evaluate their own performance. Although research is being conducted on adaptive controls to improve machining efficiency, the remaining areas that require such human decisionmaking are many and important.

Numerical control thus offers a new environment for manufacturing. New loci of decisionmaking are being evolved and methods of information generation and transformation are undergoing change in plants which process material flowing through them. In this environment, machines are used to execute the instructions of the people involved in the process, leaving the people free to explore new solutions for manufacturing problems.

Machine Operations

The Control Function. The central element of numerical control is the feedback principle. Feedback is the word used to describe the reporting of a difference between a desired condition and an actual condition. A simple example is the home thermostat: Whenever the actual temperature departs by more than an acceptable amount from the desired temperature, an electrical signal is transmitted to the thermostat. This signal controls a relay which turns on the furnace. As soon as the actual temperature is sufficiently close to the desired temperature, the thermostat ceases to transmit a signal, and the furnace is shut down. The signal generated by the thermostat is called an error signal, and its presence results in action designed to remove the error.

Servomechanisms are devices which act to correct an error signal. In numerically controlled tools they control the motions of the machine tool slides. When each slide is in the desired position, no error signal is generated; if any slide were to depart from the desired position, an error signal would be generated, and the servomechanism would act to eliminate the error signal.

The controller causes the machine tool slides to move by generating signals that have the same effect on the servomechanisms as their own error signals. They act to eliminate the error, and in doing so, take up the new desired position. The resolution of a numerical control system is determined by the smallest distance the servomechanisms are able to detect. Control systems that can resolve two ten-thousandths of an inch are now routine.

In conventional machining, the definition of the part desired is generally contained in the blueprint or drawing. In the numerically controlled manufacturing process, the blueprint is used to obtain the control tape which then serves as the definition of the desired part.

The Machine Tool. Almost every kind of machine tool has been fitted with numerical controls: milling machines, punch presses, lathes, drilling machines, jig borers, and grinders. In addition, machines not normally considered machine tools have been equipped with numerical controls: welding, filament winding, flame cutting, drafting, and wiring machines.

Consider a conventional drill press. To drill a hole in a piece of material, the material is positioned under the drill, and the drill is lowered at a speed which will tax neither the drill bit nor the motor of the machine. In a numerically controlled drill, the material is firmly attached to a table which can move in and out along one slide and from side to side along another slide. The spindle containing the drill bit can move up and down. These three directions of motion are at right angles to each other and form the basis of a coordinate system. Every position into which the machine tool can be moved has associated with it a unique set of numbers, one of which stands for the position of the in and out slide, one the side to side slide, and the other the position of the spindle slide. These three numbers are called the coordinates of that position of the tool. If it is desired that the machine tool take up a certain position, the coordinates of that position are punched into the control tape.

Many numerically controlled tools can only cut straight lines. These machines can be programed to machine curved parts by determining a sequence of linear cuts which never depart from the curved surface by more than an acceptable tolerance. While the curve that will be machined will really be a sequence of straight lines, it is sufficiently close to the desired curve to be acceptable. To instruct the machine tool to approximate the curve, it is necessary to supply the coordinates of the endpoints of the straight line cuts. Computers are used most extensively in numerical control processes to compute the values of these coordinates and to punch them into the control tape.

More complicated machine tools than the drill press are in common use today. Four- and five-axis machines have four or five axes of motion, respectively, the extra coordinates indicating the position of the additional slides. Five-axis tools allow virtually any orientation of the cutting tool to the piece part, eliminating intermediate setups almost completely.

Automatic tool changing devices have been developed for different types of machine tools. Used in conjunction with a five-axis machine, an automatic tool changer allows parts that once had to be transferred from machine to machine to be completely manufactured with a single setup. Machine tools as sophisticated as these are generally called machining centers. Their productivity is so high they can often replace 8 to 12 machines. However, because they are so productive, a premium is placed upon their effective use. Careful programing of these tools is essential if maximum time is to be spent in the actual production of parts.

While the servomechanisms attached to a machine tool may well be thought of as a part of the control system, they are more often considered part of the machine tool. Servomechanisms are selected based upon the horsepower requirements of the machine tool slides, and the nominal mass of the machine tool. Changes can be made in control systems without changing the servomechanisms.

The stability, or reliability, of the servomechanisms can substantially reduce inspection costs, since the stability of the servomechanisms will guarantee repeatability within limits generally acceptable to pass quality assurance tests. The inspection task is thus reduced to checking the first part thoroughly, and subsequent parts cursorily.

The Controller. There are two types of numerical control systems in use today: the point-to-point or positioning control, and the continuous path control. The essential difference between the two systems is that in the point-to-point control there is no coordination of the motions of separate axes, while in the continuous path control the displacement along any axis is proportional to the displacement of the other axes, i.e., if the x-axis has been displaced one-half of the commanded x-axis displacement, the y-axis is at that same instant displaced one-half of the commanded y-axis displacement. Thus, in the positioning control, the programer may not select a linear path between two points if more than one axial displacement is required.

The configuration for these control systems most often includes a paper-tape reader, with the commands for the controller encoded in the perforations of the paper tape. Some systems include, in addition, facilities for a "manual" operation of the tool; in this mode, the coordinates desired are defined by positioning dials and pressing a switch to indicate that the information indicated in the dials is to be interpreted as a command. Control media such as magnetic tape, plugboards, or dials may be used as the sole input. (See appendix B for definitions.)

The positional control finds its greatest application in drilling, boring, and tapping operations, where the tool is to be precisely positioned above the work, and the operation is to be performed involving only a vertical axis. In applications such as milling, the point-to-point control has little utility, although it is possible to decompose straight line cuts into a sufficiently large number of alternate axial movements so that the smoothing inherent in all physical systems will result in approximately the motion desired. Continuous path systems, since they include both positioning and path control, may perform the work of point-to-point systems.

The positioning accuracy and speed of controllers of both types make it possible to execute extremely intricate maneuvers in a short period of time. In a drilling operation, movements of the tool outside the workpiece may be executed at maximum speed, while for drilling in contact with the workpiece, the speed lineup may be precisely controlled. These rapid changes in speed cannot be effected by a human operator working with a conventional tool and are a major contributing factor in reducing machining time.

The full resolution available from controller manufacturers is not used extensively today. Most positioning systems are accurate to one-thousandth of an inch. Contouring systems are generally accurate to two ten-thousandths of an inch. These resolution levels are a result of the economics of tool procurement in which the minimum tolerance adequate to the range of machining to be done has been selected to keep the cost of the control system at a minimum. The dimensional stability of the machine tools equipped with these controls does not allow exploitation of finer resolution. Yet one controller manufacturer has announced the capability of producing a control system with a resolution of ten-millionths of an inch. Special control systems may be in use in defense applications which begin to approach this level of resolution, but information on these systems is not available. Numerical control may be extended into a limited number of applications as the machine design improvements necessary to operate effectively at the finer resolution are developed.

Many special functions are available under control of the numeric input. Controllers are capable of recognizing a large number of special codes which activate special functions. Some of these functions affect the normal operating mode of the control. For example, circular and parabolic interpolation are available; these allow precise control of the machine tool path so that it will follow a circular or parabolic arc instead of a straight line. This capability is especially valuable in machining applications where the stresses that result from the faceting normally encountered with linear paths are not acceptable. These changes in the mode of the control are affected by using different electronic hardware to generate the circular or parabolic cuts. Other special functions affect the operation of the machine tool or its accessories. Coolant may be turned on and off, transfer functions may be initiated or awaited, or particular gear ranges selected. In the specialized machines, the current in electric welding machines or the gas mixture in flame cutting tools may be regulated under program control.

Considerable capability is available in controller hardware today since controllers are digital/analog special purpose computers. There has been a considerable shift toward the use of large general purpose digital computers with their inherent flexibility to replace special controller functions at the machine tool. It is expected that the demand for special controller functions will thereby be reduced.

The Computer. The computer has served to create an environment favorable to the development of NC technology; it was instrumental in the early development and use of NC, and today serves as an important part of the NC process. Inasmuch as a large amount of data is required for a detailed description of conceptually simple parts, the computer's capability to process large volumes of data with low error rates uniquely qualifies it for use in numerical control. The one-half to 3 million bits required to contour a typical production part, for example, is testimony to the skilled machinist who formerly assimilated this information in his craft. The computer, however, can generate more bits, store them, and sequentially read them out to control the machining process at less cost and with a reduced error rate. Manual methods for preparing controls, too, are at least twice as costly as computer methods.

The calculations required for the description of tool paths are relatively simple but recur thousands of times. The computer's ability to execute programs describing these calculations economically and recall them for later use is the characteristic which has dictated its extensive use in numerical control up to the present.

Part programers who work without computers use a small number of programing techniques because they can maintain accuracy and proficiency with only a few at a time. Part programers who work with computers use a large number of techniques without having to be familiar with the mathematical operations performed by the computer.

Special languages for defining a part have been developed which allow the part programer to describe geometric shapes and define the motions of a tool with respect to these shapes. The language is nonmathematical and oriented to the information sources of the part programer. The APT language is the most widely used today. Some examples from it are:

Definition of point:	PPX47=POINT/2, 3
Definition of line:	JPLAN=LINE/INTOF, LINE01, LINE02
Definition of circle:	CONCIR=CIRCLE/CENTER, PPX47, RADIUS, 1.94375
Motion along a circle to a line:	GOLFT/CONCIR, JPLAN

Comparative figures for manual and computer programing times were recently obtained by programing identical parts at two separate divisions of a large aerospace company. The APT programing for drilling 101 holes in a disc, for example, required 1 man-hour compared to 15 man-hours required for manual programing. Manual programing of contour turning for lathe surface finish 18–22 microinches required 40 man-hours while APT programing required only 4 man-hours.[2]

The use of numerical control might have been much broader today if all industries had computers as accessible as the aerospace industry. The computing load attributable to numerical control within the largest aerospace users is about 10 percent. The only alternative to preparation of the control tape at a remote computer center until now has been the use of a small computer devoted exclusively to numerical control. A limited but fairly useful subset of the APT language, ADAPT, is available on three small computers at present, but is not widely used. Earlier languages, AUTOSPOT and AUTOMAP, are still in use.

Remote data communications equipment is now coming into practical use. A data link is established between the offices of a user and a large computer center. The user's input/output device is similar to a teletype unit and leases for about $50 per month. Common telephone lines are used for low volume communications and station-to-station rates apply. The input/output device is used in much the same way as the console typewriter of a small computer. The lower cost per computation available with the large centralized computer makes the arrangement economically attractive. Widespread use of data links for general purposes is expected within the next 2 to 5 years. Since the data link combines the minimum capital outlays associated with the small computer with the fast turnaround and power of the large computer, one of the last barriers to the use of the computer by the small shop for numerical control programing seems ready to fall.

Productivity of Machine Tools

Productivity is a measure of a machine's capability for producing parts and the term is generally used in a relative sense. There is no absolute standard of productivity, nor are there units of productivity. Nevertheless, it is a concept frequently encountered in the discussion of the nation's machine tool inventory. As a machine tool ages, its productivity is generally considered to decrease, since those characteristics of its performance which are taken to contribute to productivity are deteriorating.

An important method for measuring changes in productivity has been developed by Dr. Lawrence C. Hackamack of Northern Illinois University, called the Productivity Criteria Quotients (PCQ) rating.[3] Characteristics of a class of machine tools which contribute significantly to the productivity of a class of machines have been identified, and these productivity criteria have been developed through a survey of the industries involved.

The criteria have a direct bearing on the effectiveness of the machine and are associated with critical elements of design and construction. An appropriate weight is assigned to each criterion. The PCQ rating is obtained by taking the weighted sum of the critical criteria that change in a year and dividing by the number of machine lines in a defined category.

Critical criteria for the category of horizontal boring and milling machines, for example, include: automatic controls, feeds and speeds, bed and way, column design, clutches, less spindle drift, horsepower, ability to hold tolerances, and additional features.

The PCQ ratings for 12 classes of machine tools for the years 1950–64 are presented in table 1. The total of the PCQ ratings for each year is plotted in figure 1.

[2] G. E. Jerahov, "APT's Contribution to NC Manufacturing Efficiency," *Western Machinery and Steel World*, Feb. 1964.

[3] *American Machinist*, Special Report No. 570, 109, (12), June 7, 1965, pp. 129–140.

TABLE 1. PRODUCTIVITY CRITERIA QUOTIENTS, 12 MACHINE TYPES, 1950–64 (1939=base year)

Machine type	Productivity Criteria Quotient														
	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Horizontal boring and milling machines [1]	172	216	220	222	242	276	[2] 300	[2] 350	364	[2] 382	[2] 472	[2] 484	[2] 496	496	504
Vertical turret lathes [1]	190	195	300	330	330	405	435	[2] 470	[2] 505	[2] 630	645	[2] 660	[2] 675	[2] 695	695
Jig borers [1]	94	94	94	94	94	124	[2] 137	[2] 170	173	[2] 196	[2] 253	253	253	253	[2] 270
Sensitive drills [1]	8	8	10	10	10	22	26	32	[2] 48	52	[2] 70	70	[2] 78	[2] 83	[2] 96
Radial drills [1]	32	32	32	32	32	67	75	[2] 83	[2] 103	[2] 115	[2] 165	165	165	165	165
Engine lathes [1]	170	173	178	184	189	280	286	287	290	309	[2] 391	391	[2] 395	395	[2] 408
Turret lathes [1]	188	208	213	225	253	311	343	343	[2] 373	383	[2] 465	478	478	490	505
Surface grinders [1]	50	58	63	68	78	80	80	107	115	118	152	152	154	167	[2] 180
Cylindrical grinders	145	145	145	150	155	180	202	205	227	247	272	272	272	272	272
Milling machines	80	80	80	80	80	150	158	168	168	174	198	200	200	200	204
Contour saws	63	63	70	77	77	77	77	77	90	90	93	93	93	93	93
Cut-off saws [1]	12	12	12	26	32	32	50	64	72	[2] 86	96	99	99	102	105
Total PCQ	1,204	1,284	1,417	1,498	1,572	2,004	2,169	2,356	2,528	2,782	3,272	3,317	3,358	3,411	3,497

[1] Automatic controls included in critical criteria.
[2] Indicates year of improvements in automatic controls.

SOURCE: Special Report No. 570, *American Machinist*, 109, (12), June 7, 1965, pp. 129–140.

The year to year modifications in almost all of the machine tool classes show increases in productivity. The machine classes that include automatic controls among their critical criteria are indicated in table 1, together with the year in which a significant improvement in this criterion occurred. The 1965 data are expected to show a surge in growth similar to the 1955 and 1960 data since many improvements are announced to coincide with the machine tool expositions held every 5 years.

Numerical control, classed in the PCQ ratings under automatic controls, is but one of the relevant criteria. The PCQ ratings, however, do not adequately reflect the impact of numerical control on the productivity of machine tools since the weighting scheme used allows a maximum weight of three to be assigned to an improvement. Numerical control has not yet had a sufficient impact upon the manufacturing environment as a whole for its contribution to productivity ratings to become apparent to the industry.

The productivity criteria quotient ratings are concerned only with individual machine tools. However, the manufacturing environment in which the tools are used also determines the extent to which their potential for productivity can be exploited. Proper scheduling of machine tool use, the availability of adequate inventories, and a market for the products of manufacture are examples of contributing factors.

It has been estimated that nearly two-thirds of the Nation's tool inventory is 10 or more years old. Using the total PCQ ratings as a rough measure, the productivity of the present machine inventory can be estimated. Since the 1954 PCQ rating was 1,572 compared to the 1964 rating of 3,597, two-thirds of the present machine tool inventory are less than half as productive, considering the 1954 new state, as machines currently available. This estimate does not take into consideration different PCQ differentials for the various machine classes nor the specific capabilities of NC machines.

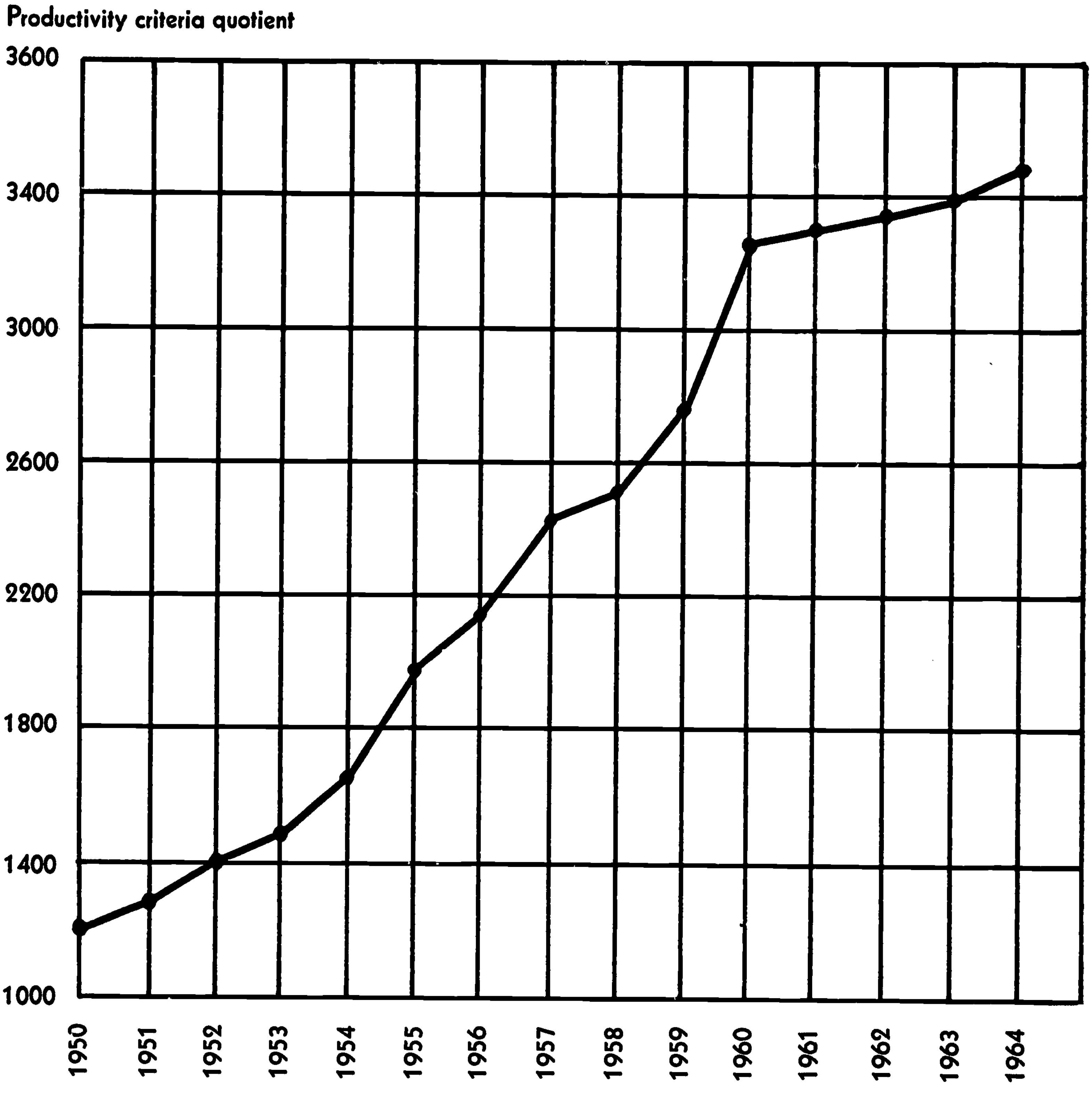
It is generally accepted in the industry that numerical control offers a dramatic increase in the productivity of machine tools. A rule of thumb often used is that a numerically controlled tool offers a fourfold increase in production for a twofold increase in cost. In fact, increased production of numerically controlled tools is reducing their cost and technological development is increasing their production capacity. Actual machining time for parts produced with numerically controlled tools is only 20 to 30 percent of that required where an operator is directly involved. Tooling and fixture costs may be reduced 70 to 80 percent since standard fixtures applicable across a wide range of parts may be used in place of the complicated fixtures previously used. Machine utilization has increased since accurate estimates of machining time developed during computer processing allow accurate scheduling. The overall error rate of the manufacturing process can be cut in half since errors in the execution of the design formerly due to human failure are drastically reduced.

The increased productivity of numerically controlled tools reduces labor costs per part and makes 24-hour operation of the tools profitable. The calendar life of numerically controlled tools may, therefore, be substantially less than for conventional tools, with numerically controlled tools requiring replacement in 7 to 15 years. The shortened life cycle of numerically controlled tools will contribute to accelerated development of NC techniques.

Future Applications of Numerical Control

Manufacturing Applications. The current state of the art in controller technology will allow for considerable extension of the machines to be controlled. Numerical control is now sufficiently

FIGURE 1. *Total Productivity Criteria Quotients, 1950–64*



SOURCE: *American Machinist*, June 7, 1965.

developed so that it may serve as the basis for completely new manufacturing techniques. Three examples are microfabrication, microassembly, and optics. Microfabrication describes the use of well-known fabrication methods for very small parts. The demand for miniaturization during the next decade will be sufficient to support considerable development efforts directed toward the reduction of costs. The present techniques for the development of solid state electronic components and integrated circuits require carefully controlled manufacturing conditions. Tooling is the term normally applied to the preparations now made for the production of these circuit components. The use of numerical control in place of the chemical erosion of photographically prepared materials may provide sufficient economies in tooling and flexibility to justify its use. Microfabrication may thus prove to be one of the new areas of application of numerical control.

Microassembly describes the assembly of very small parts. The techniques now used for control of automatic assembly equipment may prove too costly or unreliable for use with very small subassemblies. The inadequacy of physical stops or timing devices may be overcome by exploiting the positioning capability and the ability to control the path of tools inherent in numerical control.

The manufacture of spherical lens elements is well developed and reasonably economical. Aspheric elements, on the other hand, are difficult to manufacture. The use of aspheric elements in optical systems would reduce their complexity. With methods presently in use, the cost of the finished system is much higher. If the positioning accuracy of numerical control can be brought to bear, however, the manufacture of aspheric lens elements could be sufficiently economical to warrant the development of the necessary manufacturing techniques.

These examples are presented to demonstrate that the use of numerical control in manufacturing has room for still further expansion. In all of these cases, the appropriate machinery and techniques are still to be developed. The development of new applications in the next decade is likely to include a period that roughly parallels the development that has occurred in the metalworking industry during the last decade.

Other significant areas where numerical control and computer-oriented techniques will develop are general fabricating, transfer, and assembly operations. Some of these were discussed above. The full implications of automation in these nonmachining areas are discussed in part 2 of this report.

Numerical Control in Drafting. A few companies are now using numerical control extensively in the preparation of engineering drawings and blueprints. The complete elimination of the draftsman's role is not likely, although it is expected to undergo significant change.

The initial use of engineering drawings is to define the part to be manufactured. They include a description of the materials to be used, the dimensional tolerances that must be maintained, and the relationships among components. A secondary use for engineering drawing is for later reference, i.e., to serve as documentation for the part that was produced.

The use of computers to produce control media on a routine basis will have the effect of making the graphic presentation of the part geometry unnecessary as a preliminary to manufacture. A simple sketch will be adequate to the needs of the part programer. It will no longer be necessary to detail the part on paper before manufacturing it on the machine tool.

The definition of the part in sufficient detail to allow the computer to prepare the control media will have two significant byproducts: the definition language and a computer generated drawing. The separation of descriptive information from the drawing itself will allow the economic generation of drawings by computer. Used in conjunction with the definition provided to the computer, the simpler drawing will be sufficient documentation for engineering changes and/or remanufacture. More immediate uses will include a verification that the part manufactured meets the original design intent and a definition of the part for inspection purposes.

The draftsman may be required to augment or clarify the computer drawing. It is most likely, however, that only a small amount of his time will be given over to the insertion of symbols or letters by hand. The draftsman will use his presentational skills to determine how the drawing needs to be augmented and will prepare instructions that, upon input to a computer, will result in a new drawing.

The techniques developed to allow the computer based preparation of engineering drawings will have an effect outside the manufacturing industries. Wherever the material to be presented in the drawing is routine and repetitive, the use of computers will allow significant reductions in cost. For example, the preparation of street maps, which are generally line drawings where a reasonable level of precision must be maintained, can now be automated with considerable cost savings. The preparation of topographic and other maps which require considerable skill in the use of color for the presentation of information are not likely to be early candidates for computer preparation.

Computer-Aided Design. Numerical controls make it possible to exercise control over more of the manufacturing process than the machines. The removal of the machine operator from the sequence of specialists allowed to interpret the definition of the part brings the finished part closer to the designer's specification. The use of computers in conjunction with numerical control makes possible the creation of the control tape almost simultaneous with the definition. As soon as the part has been sufficiently defined so that the remaining details may be determined on a routine basis, i.e., where judgment is not required, computer programs can be used to supply them.

If the manufacturing process is defined as the implementation of the designer's specification on a routine basis, the implication is that the manufacturing process can be completely automated. A more accurate definition of the manufacturing process must take into consideration the augmentation of the designer's specification at every level: the engineer, draftsman, tooling planner, and machinist. Each of these specialists also reviews the design for effectiveness, economy, and feasibility. It is not yet clear that any of these steps is routine. Even though the amount of review required may be reduced, adequate control of the process requires that some minimum level of review remain.

Computer-aided design is directed toward providing the designer with direct access to the computer and immediate response. The results he obtains may be stored for later recall by him or others. The practical realization of this objective will provide the basis for a high degree of automation in the manufacturing process.

Until recently the designer has not been able to obtain direct access to the computer. The lengthy calculations necessary to determine certain details of a design or predict its performance first had to be programed. The results of the calculation had to be checked for validity, and then evaluated. The sheer volume of the computer output made it necessary to prepare graphs which displayed the salient information in a compact form before it could be used. The number of steps required in the process sometimes resulted in long delays before the designer could use the computer results. Nevertheless, these procedures were used since a design of equivalent performance could not be obtained as economically with precomputer methods. The use of these procedures has been extensive enough that their function is well understood and valued by the designer.

A new device which relies upon the computer techniques already developed for the designer makes it possible to achieve an unprecedented degree of immediacy. The device is commonly called a graphics console. A display is traced on a screen by an electron stream in much the same way as the picture on a television tube is generated. The display is renewed many times each second and a lingering phosphorescence reduces flicker. The operator is provided with a light sensitive probe which detects the momentary increase in brightness when the display is renewed. Since each portion of the display is renewed at a slightly different time, the computer can determine to which portion of the display the operator is pointing. Using a probe and pushbuttons, the operator can indicate which calculations are to be performed, which portion of the display is to be analyzed, where the results are to be displayed, and the scale and orientation of the display.

The information relating to the display can be stored indefinitely for later use by the designer or others. As new information is added to the display, either through computation or direct specification, it becomes part of the information that can be recalled later. Any part of the display may be modified, so that several design approaches may be analyzed and evaluated before the final selection is made. The designer has a direct line to the computer so that even very complex analyses can be performed and displayed within a short period of time.

Recent developments in computer technology have made computer aided design economically feasible. Time sharing allows a computer to switch rapidly from task to task so that many graphics consoles can be serviced by a single computer in much the same way as a chess master can play against many opponents simultaneously by using different boards. The cost to the individual user is thus greatly reduced while the capabilities of a large and powerful computer are still provided. Storage devices which enable the computer to retrieve quickly large quantities of data are now becoming available.

The graphics console may ultimately be used for more than design. Additional information can be added to the computer based description of the part by the engineer, tooling planner, and part programer either through direct insertion or by calling for additional computation. As soon as sufficient information becomes available, a control tape can be prepared to fabricate the desired part. In this way, various specialists, working as a team, can augment the design while retaining effective control through review.

Computer aided design is now being investigated by several aerospace companies and at least two large automotive companies.

Skill Requirements and Occupational Shifts

It was pointed out above that the significant changes brought about by numerical control have been in the methods of information generation and transformation and the loci of decisionmaking associated with this information. Accordingly, shifts are occurring in the occupations and the skills required by the NC process.

Because the aerospace industries have the most experience with NC technology, we should look to them for clues to the long range impact of NC on skill requirements and occupational shifts. It is not expected, however, that the experience of this industry will transfer completely to any other industry since part of its present skills profile is due to the special character of the industry.

In the conventional machining process, the design engineer, working in conjunction with a draftsman, develops a blueprint which defines a part to be produced. Working from this print, the tooling planner develops a set of fixtures which will enable the machinist to manufacture the part on a particular machine. The machinist, following the blueprint and the rough plan established by the tooling planner in his layout of the fixtures, manually controls the machine and produces the finished part.

Numerical control technology requires a new class of specialist, the part programer. The role of the design engineer and the tooling planner is changed slightly, while the tasks of layout men, draftsmen, and machinists are considerably altered.

The design engineer, freed from the former constraint of manufacturing feasibility, is responsible for developing a complete mathematical, or at least computer-amenable, definition of the part. He can seek an optimum solution to the design problem with which he is presented.

The direct control of the manufacturing procedures is in the hands of the part programer, who works closely with the design engineer to assure that the design intent will be realized in the control tape. The part programer, in developing his description of the part and the definition of the tool path desired, is performing some of the functions previously performed by the tooling planner. Since fixturing in the numerical control environment is somewhat simpler than in the conventional environment, the part programer often selects his own tooling from a standard collection, effectively bypassing the tooling planner. The tooling planner, on the other hand, because he is now involved only in the more sophisticated and difficult parts, becomes more specialized.

In conventional machining, the machinist could "fill in" some missing detail of the design engineer's and tool planner's specification of the part. Since this information cannot be supplied by the machine operator in a numerical control environment, designs must be more explicit but need not be more detailed. Thus, in undertaking a portion of the tooling planner's role and a portion of the machinist's role, the part programer assumes a significant role in the skill profile.

Since the manuscript prepared by the part programer as input to the computer is a rigid definition of the details of the part, engineering drawings developed for documentation can be much simpler. The part programer may be able to specify a machine-drafted drawing of the part without the assistance of a draftsman. This drawing can be used as the basis for a draftsman to complete details which do not relate to the part being manufactured.

Many tool planners and machinists have made a successful transition to part programing. The basic criterion for success seems to be an aptitude for planning. Extensive mathematical training is not necessary since the computer environment requires only that the part programer formulate the problem, with the actual solution left to the computer. In-plant training courses, for example, have retrained as part programers workers with a high school education who have knowledge of trigonometry, drafting, and blueprint reading, and have experience in tool design, production planning, and machine shop operations.

The machine operator need not have long years of experience to recognize deviation of machine tool operation from a norm. His responsibility for the protection of the tool and the piece part begins with the second part produced from the control tape validated by the part programer. The NC machine operator, therefore, need no longer be a skilled machinist.

Other functions in the manufacturing environment have not been substantially affected with respect to skill profile. Maintenance of equipment seems to involve the greatest departure, since the introduction of costly and complex electronic equipment requires considerable technical knowledge. The majority of companies have had little difficulty upgrading the skill of their maintenance staff to the necessary level. The need for continued maintenance is somewhat more urgent in the numerical control environment since more production is lost per hour of downtime.

3. Diffusion of Numerical Control

A Model of Technological Diffusion

The state of the art of numerical control has been described in the preceding section, and related technological trends during the next decade were assessed. There is a long path, however, that leads from a research and development prototype model to a machine that is economically feasible in a production plant. The problems of each of the fabricating industries are different, and substantial differences exist between plants in the subgroup classifications (see appendix A) and also between plants producing the same product. The manufacturing process in a given plant may or may not be amenable to numerical control. Cost factors, competition, the state of presently used equipment, changes in industrial and consumer demand, and the introduction of new materials and new processes will determine the diffusion of numerical control in the fabricating industries.

The rate of diffusion is dependent upon the aggregate of decisions which plants make in accordance with the following criteria:

1. Is the technology amenable to the unique circumstances of the individual plant?
2. Is the technology economically feasible, that is, will its introduction result in savings (labor, material, work space, inventory, etc.) and increased productivity?
3. Can the capital investment required for equipment, retraining, and maintenance be justified and obtained?

To arrive at a qualitative evaluation of the diffusion rate of numerical control in the fabricating industries, a model of the technological diffusion process is first described. The model is then studied in light of numerical control developments during the past 10 years coupled with forecasts for the immediate future.

Technological diffusion in an industry is a four-stage process. The first stage is the pretechnology or traditional stage of industry during which the new technology is developed within the framework of the old. The new technology or invention develops the concept of a new product or process and reduces it to practice. The invention is often the result of the expenditure of large sums of money for research and development. The early prototypes are usually crude and primitive in contrast with developments in the third stage. They are costly but justified on the basis of present technical and future economic potential. Their range of utilization is usually restricted to particular applications. In the stage of pretechnology, the new invention appears as a laboratory curio.

The second stage of diffusion is one of transition. The prototype models leave the laboratory and are established as a product line in their own right. Better models in a price and size range are developed for an expanding number of applications. Most important, new and unexpected uses are discovered for the technology as utilization expands and users become acquainted with the technical and economic potentials. Widespread use is still restricted by lack of availability of equipment, high costs, and unfamiliarity. Initial installation is often made on the basis of technical necessity, management intuition, and a pioneering spirit.

The third stage is the takeoff period. The technological and economic potentials of the invention are perceived by expanding numbers of possible users, and skills in employing the new technology become more widespread as equipment becomes increasingly general purpose. More model lines are exhibited at prices which become competitive with older methods, and economic justification for adaptation of the new technology is more readily amenable to traditional management formulas. It is during this period that an expanding utilization of the new technology occurs.

The fourth stage is that of maturity. The new technology becomes rapidly diffused over the field of its potential users as acceptance spreads. The quality and reliability of the new technology commands ever wider utilization. Manufacturing facilities are developed for a mass market. Prices and model lines meet varying needs and capabilities. The new technology, in short, becomes a standard part of the traditional.

This four-stage development is well illustrated in the case of computers. The Mark I was developed at Harvard University in 1944 in the period of computer pretechnology, and by 1948 a dozen large scale automatic digital computers had been "hand built" at elaborate cost and placed in laboratories and engineering centers. Costing millions of dollars, the computers were large, slow in operation, and used for special applications.

In 1951 the transition stage began when the Bureau of the Census installed its first commercial computer. By the end of 1954 nearly 2,700 computers had been installed, the product of 10 manufacturers. The concurrent technological revolution in solid state devices, namely, the transistor, led to smaller, faster, and cheaper general purpose computers.

By the close of the 1950's, computer technology had entered its takeoff stage with nearly 10,000 computers installed in various industries and applications. At the end of 1963 the computer industry offered over 100 different models manufactured by 25 companies and had achieved an annual sales volume approaching $2 billion. Nearly a million people were engaged in computer design, development, operation, programing, and maintenance.

At mid-1965, computer technology is entering the stage of maturity as the number of computers installed approaches the 28,000 mark (over 11,000 unfilled orders) [4] and the area of utilization reaches into all facets of industry and commerce. The small computer (renting for below $12,000 monthly) is the fastest growing segment of the industry and accounts for 89 percent of the total installations, up from 75 percent in 1955. Medium computers now account for 7 percent, and large computers represent only 4 percent of the total, a decrease from the 1955 figure of 16 percent. The third generation computers which stress modularity and time-sharing are being associated with the rapidly expanding technology of data communications. Predictions for 1970 estimate 100,000 computers in use in the U.S.[5]

Numerical Control 1954-64

The first prototype numerically controlled machine was developed at MIT under Air Force sponsorship in 1952. During the period 1954-58, 193 NC machines with a value of over $31 million were shipped. In the single year 1959 the 203 NC machines shipped exceeded the figure of those that were shipped in the previous 5 years. The figure doubled in 1960 and has increased continually in succeeding years, reaching 1,517 NC machines shipped in 1964. The total for the 11-year period is 5,100 machines with an aggregate value of $384 million. Detailed figures including a breakdown by type of numerical control and by type of machine appear in table 2. (See appendix B for definition of types of numerical control.)

In the first 5 years of NC, 3.8 percent of the total number of NC machines shipped through 1964 were produced. During 1959-61, 22.0 percent of the total were produced, and in the last 3-year period, 1962-64, 74.6 percent of the 5,100 were produced.

Investment in controls amounted to 29.4 percent of the cumulative investment over the period 1954-64. Controls are often manufactured by a different manufacturer than the machine tool maker and are assembled into an integrated system by the machine tool maker.

Point-to-point positioning machines comprised the bulk of the shipped machines, 71 percent of the 11-year total. The more sophisticated continuous path machines constituted only 12 percent of the total. The 613 continuous path machines had an average cost of $198,100 compared to an average cost of $50,800 for the point-to-point machines.

Nearly half of the total NC machines shipped during the 11-year period were drilling machines with an average cost of $31,300. The 834 NC boring machines were second in total quantity, averaging $104,200 per machine. Costing an average $128,800, the 813 NC milling machines were third in total quantity. The average NC lathe cost $98,800.

The above figures (which include cost of controls) are indicative of the cost differentials of NC machines in both type of machine and control. Although reductions in average costs are already noticeable, in general, the cost of an NC machine is still much greater than its conventional counterpart.

The cumulative total of NC machines shipped during 1954-64 is graphed in figure 2 together with the dollar value of the annual shipments. By mid-1965 more than 6,000 NC machines are estimated to be in the field. The total is expected to increase more sharply by the end of 1966, when an expenditure of $318 million in an 18-month period is expected to produce an inventory of over 10,000 NC machines.[6]

In a period of 6 years the annual investment in NC machines has jumped from $17.3 million in 1959 to $105.5 million in 1964, an increase of over 600 percent. The expected expenditure in the next 18-month period of $318 million represents 82.8 percent of the cumulative expenditure in the period 1954-64.

Although the rapid growth of NC machines is impressive in an absolute sense, it is instructive to view this growth against the background of the total metalworking machinery output. The total number of machines shipped in the years 1959-64 is shown in the left-hand section of table 3.

Beginning in 1959, the first year for which annual NC figures are available, NC machines constituted 0.10 percent of the total output of metalworking machines. This percentage has increased every year since 1959, and in 1964 NC machines made up 0.72 percent of the total. Although the percentage has increased more than seven times in the 6-year period, the percent of

[4] Monthly Computer Census, *Computers and Automation*, Sept. 1965.

[5] *Computer Design*, Apr. 1964.

[6] *American Machinist*, 109, (18), Aug. 30, 1965.

TABLE 2. SHIPMENTS OF NUMERICALLY CONTROLLED MACHINE TOOLS BY TYPE OF CONTROL AND TYPE OF MACHINE, 1954–64

Item	1954–58 [1]			1959 [1]			1960 [1]			1961 [1]		
	Number machines	Value of shipments ($1,000)		Number machines	Value of shipments ($1,000)		Number machines	Value of shipments ($1,000)		Number machines	Value of shipments ($1,000)	
		Machines + controls	Controls only		Machines + controls	Controls only		Machines + controls	Controls only		Machines + controls	Controls only
Total NC machines	193	31,196	6,951	203	17,303	4,617	402	34,726	9,397	518	48,335	11,879
By type of numerical control:												
Point-to-point positioning	85	4,996	1,456	122	7,458	2,444	278	19,003	6,949	308	21,140	7,516
Continuous path activated by tape or punched card	71	20,448	5,210	39	6,742	1,960	34	4,974	1,863	64	8,892	3,182
Dial or plugboard type or prerecorded motion program control	37	5,752	285	42	3,106	213	90	10,749	585	146	18,303	1,181
By type of machine:												
Boring machines	36	3,853	1,018	42	3,632	982	100	8,379	2,535	126	12,733	3,915
Drilling machines	43	1,749	406	77	2,883	947	142	5,815	1,980	183	7,680	2,790
Milling machines	68	20,282	5,215	60	7,922	2,502	94	10,658	4,316	76	10,054	3,712
Lathes } All other	46	5,312	312	24	2,866	186	66	9,874	566			
Lathes										56	2,577	976
All other										77	15,291	486

Item	1962 [1]			1963 [1]			1964 [2]			Total 1954–64		
	Number machines	Value of shipments ($1,000)		Number machines	Value of shipments ($1,000)		Number machines	Value of shipments ($1,000)		Number machines	Value of shipments ($1,000)	
		Machines + controls	Controls only		Machines + controls	Controls only		Machines + controls	Controls only		Machines + controls	Controls only
Total NC machines	1,047	63,788	21,596	1,220	83,569	29,460	1,517	105,475	29,224	5,100	384,392	113,124
By type of numerical control:												
Point-to-point positioning	779	33,005	12,754	906	46,248	17,352	1,145	52,369	14,965	3,623	184,216	63,436
Continuous path activated by tape or punched card	111	20,371	6,606	122	23,366	8,806	172	36,683	11,231	613	121,476	38,858
Dial or plugboard type or prerecorded motion program control	157	10,412	2,236	192	13,955	3,302	200	16,423	3,028	864	78,700	10,830
By type of machine:												
Boring machines	148	16,364	4,788	184	20,588	7,112	198	21,356	6,714	834	86,905	27,064
Drilling machines	608	16,019	6,597	637	18,502	7,311	821	26,094	7,869	2,511	78,742	27,900
Milling machines	100	16,468	6,020	142	21,455	8,427	273	17,954	3,956	813	104,793	34,148
Lathes	123	6,565	2,518	192	11,882	4,508	146	31,654	9,477	548	54,137	17,864
All other	68	8,372	1,673	65	11,142	2,102	79	8,417	1,208	394	59,815	6,148

[1] Series BDSAF-630(63)-1.
[2] Series M35W(64)-5.

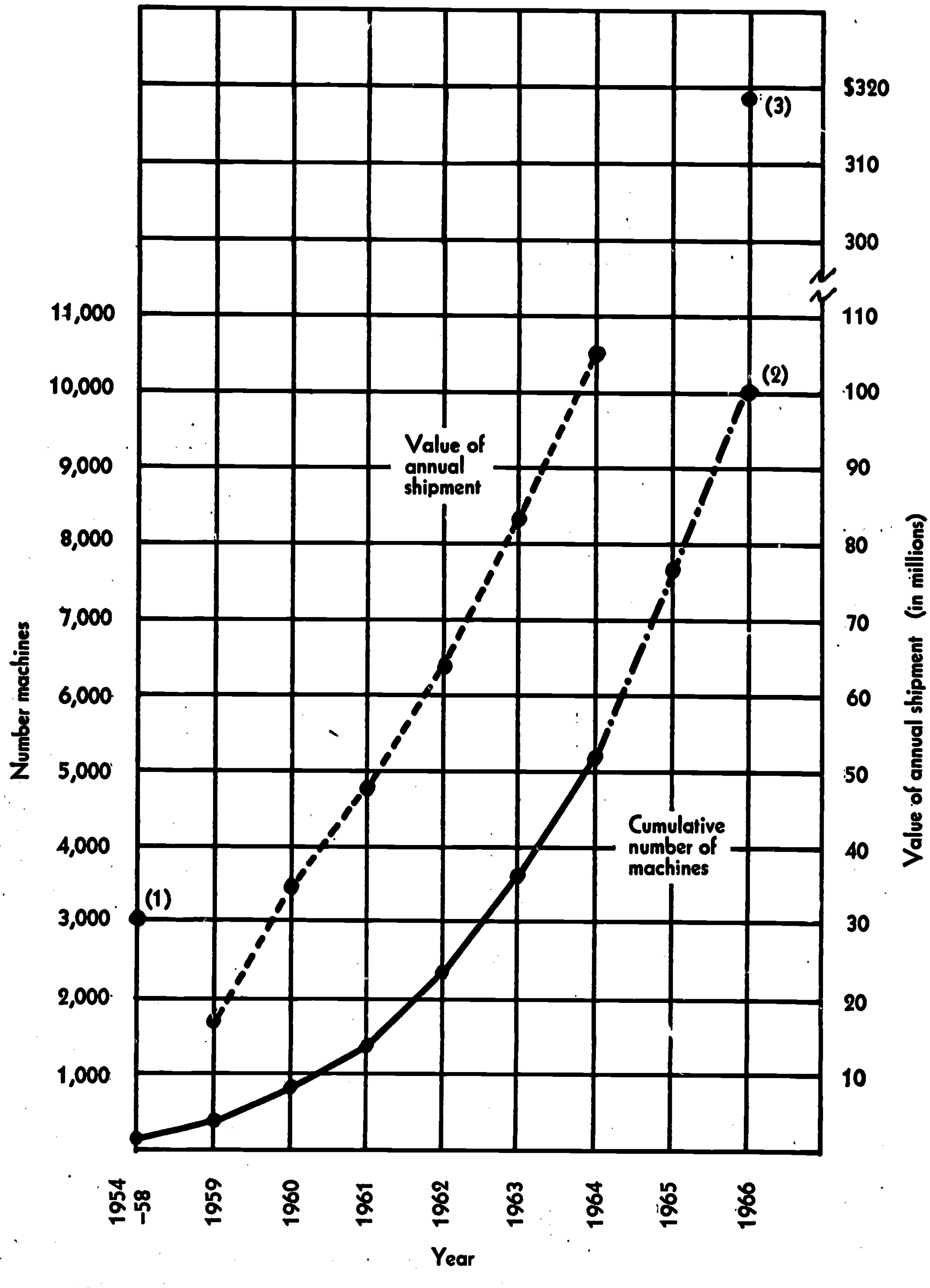
Source: Bureau of the Census, *Current Industrial Reports.*

NC machines constituted only a tiny fraction of the total number shipped in 1964.

To interpret better the small percentage of metalworking machines that are NC, the figures of table 4 are presented. Machines with an average value under $1,000 are classed as light industrial machine tools. Those with average value of $1,000 or over are classed as heavy, general-purpose metalworking machinery. In 1963, only 36 percent of the total metalworking machines had an average value of $1,000 or over, the category which would include NC machines. The 48,791 metal cutting machines with an average value of $1,000 or over constituted only 25.4 percent of the 191,992 metalworking machines shipped in 1963. Inasmuch as most NC machines were of the metal cutting type and cost, on the average, more than $1,000, it is more meaningful to consider the relation of NC machines to this figure. The 1963 figure of table 3 would then be revised to 2.5 percent instead of 0.64. The percentage figures for other years would also be increased by relating NC machines only to those metal cutting machines with a value of $1,000 or over.

Table 5 shows the value of shipments (including exports) of metalworking machinery, by class of product, for the years 1954–64. In 1964 less than 7 percent of the total number of machines were exported. It is noted that the total value for all metalworking machinery dropped over a half billion dollars in the recession year of 1958, and by 1964 had not yet returned to its prerecession figure. The 1964 total of $1.21 billion, $875 million for metal cutting machines, marked a considerable increase over the preceding year. Metal cutting machines account for approximately 70 percent, on the average, of the total value of metalworking machines.

FIGURE 2. *Cumulative Totals, and Value of Annual Shipments Numerically Controlled Machine Tools, 1954–64*



[1] Cumulative value, 1954–58. [2] 18 months ending Dec. 1966. [3] Estimated 18 month value.

TABLE 3. NC MACHINES AS PERCENT OF TOTAL MACHINES SHIPPED, VALUE OF SHIPMENTS, AND EXPENDITURES FOR NEW MACHINERY IN FABRICATING INDUSTRIES, 1959–64

Year	Machines shipped			Shipments value			Expenditures for new machinery and equipment	
	Total	NC	Percent NC	NC ($1,000)	Percent NC total	Percent NC metal cutting	Total [7] ($1,000)	Percent NC value
1959	[1] 196,701	203	0.10	$17,303	2.55	3.69	$1,907,809	0.91
1960	[2] 183,142	402	.22	34,726	4.47	6.44	2,096,572	1.65
1961	[3] 170,755	518	.30	48,335	6.32	9.10	1,974,162	2.45
1962	[4] 192,958	1,047	.54	63,788	7.36	10.18	2,270,837	2.81
1963	[5] 191,992	1,220	.64	83,569	9.08	12.97		
1964	[6] 212,195	1,517	.72	105,475	8.74	12.06		

[1] Series M35W-09, July 19, 1960.
[2] Series M35W(60)-5, July 7, 1961.
[3] Series M35W(61)-5, July 5, 1962.
[4] Series M35W(62)-5, Aug. 6, 1963.
[5] Series M35W(63)-5, July 6, 1964.
[6] Series M35W(64)-5, Sept. 21, 1965.
[7] Column sum of table 6.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Current Industrial Reports.*

TABLE 4. TOTAL SHIPMENTS OF METALWORKING MACHINERY BY AVERAGE VALUE AND CLASS OF PRODUCT, 1963

Class of product	Machinery shipped	
	Quantity	Value (in thousands)
Metalworking machinery, total	191,992	$919,884
Average value under $1,000	122,788	31,445
Average value $1,000 or over	69,204	888,439
Metal cutting type, total	138,306	644,412
Average value under $1,000	89,515	22,407
Average value $1,000 or over	48,791	622,005
Boring machines	1,733	66,851
Drilling machines	24,295	50,160
Average value under $1,000	20,521	4,041
Average value $1,000 or over	3,774	46,119
Gear cutting machines:		
Average value $1,000 or over	1,201	36,141
Grinding and polishing machines	52,070	134,246
Average value under $1,000	39,516	4,886
Average value $1,000 or over	12,554	129,360
Lathes	18,476	149,760
Average value under $1,000	7,311	4,257
Average value $1,000 or over	11,165	145,503
Milling machines	16,670	105,810
Other machines	23,861	101,444
Average value under $1,000	17,353	6,485
Average value $1,000 or over	6,508	94,959
Metal forming type, total	53,686	275,472
Average value under $1,000	33,273	9,038
Average value $1,000 or over	20,413	266,434
Presses	27,834	132,020
Forging machines	695	19,538
Punching and shearing machines	5,863	39,030
Bending and forming machines	12,738	37,278
Other	6,556	47,606

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Current Industrial Reports*, Series M35W(63)-5.

A comparison which takes into consideration values of the machines shipped is shown in the middle section of table 3. It is noted that whereas NC machines comprised only 0.10 percent of the total number of machines shipped in 1959, their value was 2.55 percent of the total shipment value and 3.69 percent of the metal cutting value. By the end of 1963, NC machines constituted 9.08 percent of the year's total expenditure on metalworking machines and 12.97 percent of the metal cutting value. In 1964 the percentage dropped slightly to 8.74 of the total value and 12.06 of the metal cutting value.

The expenditures for new machinery and equipment in the six fabricating industries are shown in table 6. The transportation equipment industry, which includes the aerospace and automotive industries, shows the largest expenditures and is followed by the machinery industry. Total expenditures ranged from $1.9 billion in 1959 to $2.2 billion in 1962.

The increasing percent of expenditure on NC machines is shown in the right-hand section of table 3 where the total value of shipments of NC machines is considered as a percentage of capital expenditures for new machinery and equipment in the six fabricating industries. The percentage rose from 0.91 percent in 1959 to 2.81 percent in 1962, an increase of 308 percent in 4 years.

How extensive is the diffusion of NC machines in the fabricating industries? Table 7 shows the distribution of manufacturers' shipments of NC machine tools by major industry group and type of control for the 10-year period 1954–63. Over 43 percent of the total, 1,543 NC machines, were absorbed by the makers of machinery (SIC code group 35). The manufacturers of transportation equipment (SIC code group 37) absorbed 24 percent of the total output of NC machines. The remainder of the NC machines were distributed among the many subgroups of the remaining fabricating industries.

It is not surprising to find the largest number of machines located in the aerospace (aircraft) industry. These 629 NC machines, 17.5 percent of the total number of NC machines with a value of 24 percent of the total value, include the largest and most advanced NC machines that have been developed. Begun with an Air Force subsidy, the NC program has become an integral part of the manufacturing process and has been further ex-

TABLE 5. VALUE OF SHIPMENTS (INCLUDING EXPORTS) OF METALWORKING MACHINERY, BY CLASS OF PRODUCT, 1954–64
(THOUSANDS OF DOLLARS)

Product class code	Class of product	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
	Metalworking machinery, total	1,229,267	961,163	1,275,942	1,281,592	671,907	679,538	777,692	764,453	867,269	919,884	1,207,106
	Metal cutting type, total	879,020	665,791	891,812	878,347	462,934	468,777	539,340	531,343	626,833	644,412	874,467
35411	Boring machines	114,443	77,372	101,838	101,976	51,563	46,248	46,939	51,547	61,366	66,851	74,056
35412	Drilling machines	86,066	53,805	65,370	56,272	30,023	33,412	38,873	36,824	53,228	50,160	72,264
35413	Gear cutting and finishing machines	48,111	36,565	49,380	38,944	22,661	24,682	34,309	36,403	35,851	36,141	47,113
35414	Grinding and polishing machines (except gear-tooth grinding, lapping, polishing, and buffing machines)	154,288	123,899	172,803	160,098	89,367	93,820	116,972	121,018	127,960	134,246	175,885
35415	Lathes	206,886	153,285	217,054	199,752	98,679	119,478	135,403	126,488	152,271	149,760	198,089
35416	Milling machines	122,518	89,573	115,817	154,973	89,315	73,275	79,438	73,710	95,787	105,810	125,798
35417	Other metal-cutting type machines (except those designed primarily for home workshops, laboratories, garages, etc.)	146,708	131,292	169,550	166,332	81,326	77,862	87,406	85,353	100,370	101,444	181,262
	Metal forming type, total	350,247	295,372	384,130	403,245	208,973	210,761	238,352	233,110	240,436	275,472	332,639
35422	Presses, including forging	216,377	170,796	240,149	238,774	76,501	84,573	104,971	111,383	109,555	132,020	33,241
35423	Forging machines (except presses)	24,412	15,599	15,489	24,714	17,387	17,900	21,057	15,816	23,706	19,538	42,698
35424	Punching and shearing machines	26,349	28,852	34,895	38,315	31,967	29,862	32,871	33,252	34,467	39,030	169,511
35425	Bending and forming machines	35,573	35,849	48,772	43,860	32,127	35,698	34,274	32,497	28,995	37,278	23,085
35428	Other metal-forming type machines	47,536	44,276	44,825	57,582	50,991	42,728	45,179	40,162	48,715	47,606	64,104

Source: U.S. Dept. of Commerce, Bureau of the Census, *Current Industrial Reports*, Series M35W(63)-5, (64)-5.

TABLE 6. EXPENDITURES FOR NEW MACHINERY AND EQUIPMENT, FABRICATING INDUSTRIES, 1959–62

Industry group	Expenditure ($1,000)			
	1959	1960	1961	1962
Fabricated metal products	$357,404	$360,430	$314,327	$390,213
Machinery	470,301	518,230	490,483	535,945
Electrical machinery	375,188	448,982	423,990	476,394
Transportation equipment	479,113	537,687	509,244	592,918
Instruments	106,746	117,151	113,834	129,737
Miscellaneous manufacturing	119,057	116,092	122,784	145,630

SOURCE: U.S. Department of Commerce, Bureau of the Census, *1962 Annual Survey of Manufactures*, Chap. 5, table 1, p. 308.

tended by the aerospace industries. The intricate problems of assembly, fine tolerances, the need to maximize strength-to-weight ratios, and the increasing utilization of exotic and hardened metals are factors that have led to the diffusion of NC in this industry. Engineers had already become familiar with computer-oriented design and production processes, and the extension of the computer to NC was a further development along these lines.

The second largest group of users of NC machines is the metalworking machinery industry and, indeed, it would be strange if the makers of automatic machines were not to use automatic machines. Leaving aside the philosophical question raised by this development—Can machines reproduce themselves?—the machine toolmakers have entered the path that leads to the automation of their own manufacturing processes.

As a background for evaluating the distribution of NC machines among the various industries, table 8 shows the number of plants with 20 or more employees in the same industry groups (1963 figures) as table 7. If we assume that each NC machine of table 7 was shipped to a separate factory, then, over all, less than 10 percent of the factories would have received at least one NC machine. This would be an upper bound on the present diffusion of NC machines in the fabricating industries. Since the one machine per factory is not a realistic assumption, inasmuch as concentrations of machines appear in aerospace, automotive, and metalworking machinery plants, the actual diffusion is over perhaps 2 to 4 percent of the fabricating industry plants.

Considering all the manufacturing plants in the United States with their more than 2 million metalworking machines, the estimated 6,000 NC machines in operation at mid-1965 constitute only 0.28 percent of the total number of metalworking machines in use.

Numerical Control, 1965–75

1965–66 Period. The rise in spending for NC tools will be spurred by the more than 100 NC machines that were displayed at the quintennial machine tool show in Chicago in September 1965. The large variety of machines displayed, the versatility of their applications, and the range of prices, offered many technological and economic advantages to prospective purchasers. A recent survey of machine tool buying plans conducted by the *American Machinist* magazine [7] corroborates the expected diffusion of NC machines.

[7] *American Machinist, loc. cit.*

TABLE 7. DISTRIBUTION OF MANUFACTURERS' SHIPMENTS OF NUMERICALLY CONTROLLED MACHINE TOOLS BY MAJOR INDUSTRY GROUP, BY TYPE OF CONTROL, 1954–63

Industry group	Description	Shipments: Total 1954–63		Point-to-point positioning control		Continuous path control		Dial or plugboard type or prerecorded motion program control	
		Number of machines	Value of shipments[1] ($1,000)	Number of machines	Value of shipments[1] ($1,000)	Number of machines	Value of shipments[1] ($1,000)	Number of machines	Value of shipments[1] ($1,000)
	Total	3,583	278,917	2,478	131,847	441	84,795	664	62,277
19	Ordnance and accessories	135	12,740	75	5,410	43	6,188	17	1,142
33	Primary metal industries	29	2,595	(2)	(2)	(2)	(2)	(2)	(2)
34	Fabricated metal products, total	273	22,298	191	12,564	35	6,742	47	2,992
341, 342	Metal cans; cutlery, hand tools, and hardware	127	10,882	---	---	---	---	---	---
343, 344, 345, 346.	Heating apparatus, structural metal products, screw machine products, and metal stampings.	103	9,491	191	12,564	35	6,742	47	2,992
348	Fabricated wire products, n.e.c[3]	11	392	---	---	---	---	---	---
349	Fabricated metal products, n.e.c[3]	32	1,533	---	---	---	---	---	---
35	Machinery, except electrical, total	1,543	87,650	1,189	59,248	93	11,980	261	16,422
351	Engines and turbines	94	11,790	---	---	---	---	---	---
352	Farm machinery and equipment	52	3,829	586	34,362	---	---	---	---
353	Construction and like equipment	171	10,225	---	---	---	---	---	---
354	Metalworking machinery	490	27,658	---	---	---	---	---	---
355	Special industry machinery	221	10,905	---	---	95	11,980	261	16,422
356	General industrial machinery	248	12,492	419	17,680	---	---	---	---
357	Office machines, n.e.c[3]	63	2,558	---	---	---	---	---	---
358	Service industry machines	26	1,398	184	7,206	---	---	---	---
359	Machine shops	178	6,795	---	---	---	---	---	---
36	Electrical machinery, total	335	18,042	293	14,157	16	2,630	26	1,255
361	Electric distribution products	29	1,820	---	---	---	---	---	---
362	Electric industrial apparatus	82	5,378	---	---	---	---	---	---
363, 364	Household appliances; electric lighting and wiring equipment.	39	1,597	---	---	---	---	---	---
365	Radio, TV, receiving equipment	12	393	293	14,157	16	2,630	26	1,255
366	Communication equipment	113	6,187	---	---	---	---	---	---
367	Electronic components and accessories	35	1,165	---	---	---	---	---	---
369	Electrical products, n.e.c[3]	25	1,502	---	---	---	---	---	---
37	Transportation equipment, total	859	100,083	485	30,738	222	51,992	152	17,353
371	Motor vehicles and equipment	194	18,344	---	---	---	---	---	---
372	Aircraft and parts	629	78,844	485	30,738	222	51,992	152	17,353
373	Ships and boats	19	1,610	---	---	---	---	---	---
374	Railroad equipment	17	1,285	---	---	---	---	---	---
38	Instruments and related products, total	68	3,235	55	2,433	(2)	(2)	(2)	(2)
381	Scientific instruments	31	1,523	---	---	---	---	---	---
382	Mechanical measuring devices	24	1,253	---	---	---	---	---	---
383, 384, 386, 387.	Optical, surgical, and medical instruments; photographic equipment; and watches.	13	459	55	2,433	(2)	(2)	(2)	(2)
	All other, including exports, educational institutions, and U.S. Government facilities.	341	32,274	(2)	(2)	(2)	(2)	(2)	(2)

[1] Represents value of machines and value of controls.
[2] Withheld to avoid disclosing figures of individual companies.
[3] Not elsewhere classified.

SOURCE: U.S. Dept. of Commerce, Bureau of the Census, *Current Industrial Reports*, Series BDSAF-630(63)-1 Aug. 28, 1964.

In the 18-month period ending December 1966, American industry is planning to spend $1.8 billion on metalworking machines. Of this amount, $1.4 billion will be spent on metal-cutting machines, the remainder on metal-forming machines. More than 70 percent of the new machines (including NC) to be purchased by plants with 100 or more employees will be used to expand production capacity; 64 percent to be purchased by smaller plants will be used to replace older machines.

Survey results indicate a planned expenditure of $318 million on NC machines in the 18-month period. As indicated earlier, this sum is 82.8 percent of the total expenditure for NC machines in the preceding 11 years. Of equal significance is the fact that this expenditure represents 17.6 percent of the total planned expenditure on all metalworking machines and 22.7 percent of the planned expenditure on metal cutting machines.

The estimated NC expenditures by industries over the 18-month period are detailed in table 9. The greatest planned expenditure for NC machines is by the aerospace industries with nearly one-third of the total expected investment. Sixty-one percent of their investment in metal-cutting machines will be for NC. Second largest invester

TABLE 8. NUMBER OF PLANTS WITH 20 OR MORE EMPLOYEES IN FABRICATING AND RELATED INDUSTRIES, 1963

Industry group	Number of plants		Industry group	Number of plants	
19		153	36		4,729
33		3,563	361	564	
34		9,321	362	586	
341–342	1,026		363–364	1,180	
343–346	6,335		365	253	
348	546		367	1,059	
349	1,089		369	422	
35		8,395	37		2,881
351	105		371	1,237	
352	561		372	700	
353	984		373	469	
354	2,053		374	69	
355	1,194		38		1,389
356	1,201		381	258	
357	266		382	306	
358	642		383, 4, 6, 7	706	
359	1,389		39		3,613
			Total		34,044

SOURCE: U.S. Dept of Commerce, Bureau of the Census, *1963 Census of Manufacturers*, Series MC63(P)-3, Dec. 1964 (revised).

in NC machines will be the metalworking machinery industry, which plans to purchase over $60 million of NC machines representing 42 percent of their total metal-cutting machinery purchases. The first and second positions in NC investment thus continue the pattern established in the first 11 years of NC.

TABLE 9. ESTIMATED NC EXPENDITURES BY INDUSTRIES

Industry	Percent planning purchases	Planned expenditures	Percent of total cutting purchases	Average per plant
Farm machinery	8	$1,300,000	4	$5,000
Construction, mining, MH equipment	24	23,100,000	52	25,700
Engines, general industrial equipment	17	14,900,000	7	15,000
Metalworking machinery	20	60,100,000	42	37,900
Special industry machinery	21	20,600,000	27	25,200
Office and service machines	----	----	----	----
Stampings, structural products	4	3,800,000	10	4,200
Fabricated metal products	5	23,100,000	6	4,100
Electrical equipment	15	15,800,000	17	17,300
Communications, electronics	25	16,400,000	44	43,200
Motor vehicles and parts	5	3,400,000	3	1,400
Aircraft, ordnance	38	109,200,000	61	142,000
Precision instruments	18	13,100,000	29	11,900
Job shops, metals, miscellaneous	9	13,300,000	25	26,800
Total	13	318,400,000	22	21,600

SOURCE: *American Machinist*, 109, (18), Aug. 30, 1965.

The construction, mining, and materials-handling industries (SIC code group 353), which purchased 3.66 percent (in value) of the 1954–63 NC output, is expected to account for 7.26 percent of the value of the NC machines to be purchased in the coming 18-month period. The metalworking machinery industry will increase its percentage of the value of NC machines from 9.92 percent purchased in the 10-year period to 18.88 percent to be purchased in the next 18 months. Aircraft (combined in table 9 with ordnance) will go from 32.84 to 34.30 percent. Special industry machinery plants (SIC code group 355) will nearly double its 10-year expenditures in the next 18 months with a planned expenditure of over $20 million. Plans of the automotive industry are cloaked in competitive secrecy and the purchase estimates are not considered to be realistic.

An indication of the growing acceptance of NC machines is the fact that 18 percent of the respondents of the 1965 survey either had or were planning to purchase NC machines. Only 2 percent were in this category in the 1960 survey. For 41 percent of those planning to invest in NC machines, this will be their initial NC purchase. The interest in NC machines is not restricted to the large plants, for a breakdown of the projected newcomers to the NC machine field shows small shops with 20 to 49 employees comprising 67 percent of this group.

The larger industries, however, will continue their role as the largest investors in and users of NC machines. This is clearly shown in table 10, where estimated expenditures for NC machines are grouped by plant size. In the percentage of companies planning NC purchases, the planned expenditures, and the average investment in NC machines per plant, the larger plants predominate.

TABLE 10. ESTIMATED EXPENDITURES FOR NUMERICAL CONTROL MACHINES BY PLANT SIZE, JUNE 1965 TO DECEMBER 1966

Number employees	Percent planning purchases	Planned expenditures	Percent of total cutting purchases	Average per plant
1,000 and over	48	$133,900,000	35	$153,700
500-999	35	54,900,000	27	71,000
100–499	18	109,100,000	21	25,800
50-99	7	11,700,000	6	2,000
20–49	4	8,800,000	6	2,700
Total	13	318,400,000	22	21,600

Source: *American Machinist*, 109, (18), Aug. 30, 1965.

Diffusion Constraints. Before estimating future growth in the remainder of the decade through 1975 it is necessary to review what may be called diffusion constraints. These constraints are factors which will tend to restrain the growing use of NC machines and impede expansion into all areas of the fabricating industries. The constraints must be carefully considered in assessing the implications of NC machine use on employment.

The diffusion constraints are discussed below in relation to (1) the machine tool industry; (2) the manufacturing (user) community; and (3) the worker.

1. The machine tool industry. The machine tool industry consists of about 900 establishments.

Approximately 425 companies specialize in the production of metal-cutting and metal-forming machines. More than 400 different machine tools are produced by the industry, with 25 firms accounting for 75 percent of the total product.

Summarizing a study that had been made of technical innovation in American industry, D. A. Schon, consultant to the Office of Technical Services, characterized the machine tool industry as follows:[8]

1. Makes little investment in research and development compared to the average manufacturing company. Only six firms conducted research in 1963. For every $1 million of production, 3 man-months of R. & D. were invested. This compared with 12.2 man-months for Western Europe.
2. Shows a low profit picture.
3. Has a considerable unused capacity.
4. Is a fragmented industry with many little companies surrounding a few giants.
5. Production has a small-run, custom job orientation geared to individual customers.
6. A strong traditional emphasis on present methods and machines.

These characteristics constitute an aggregate of inertial forces which will serve as a brake on the future growth of the NC machine tool industry.

[8] *Patterns and Problems of Technical Innovation in American Industry, Part 2: The Machine Tool Industry,* Arthur D. Little, Inc., September 1963, reprinted as Part 5, appendix III of *Role and Effect of Technology in the Nation's Economy,* hearings, Subcommittee on Small Business, Washington, D.C., 1964, part 1, p. 105.

2. The manufacturing (user) community. The manufacturing community, the potential user of NC machines, is a highly heterogeneous collection of manufacturing establishments. Table 11 shows the number of establishments in the six fabricating industries as recorded in the 1958 Census of Manufactures. The distribution of plants within each of the fabricating industries by the number of employees is given together with the total number of employees in each size classification, the total payroll, and the capital investment. Table 12 shows the number of machine shops and tool and die shops distributed among the fabricating industries in 1958.

A realistic estimate of the diffusion rate of NC machines in the more than 87,000 plants included in table 11 and the 14,511 machine shops and 6,992 tool and die shops of table 12 would require a detailed analysis, at a minimum, of the operating and economic characteristics of the many industrial subgroups in each major industry, according to product line and size of plant. The factors to be assessed for each subgroup include the following industry restrictions and economic constraints.

a. *The amenability of the manufacturing process to NC techniques*

The product line, volume of production, and fabrication methods which technologically pre-

TABLE 11. MANUFACTURING ESTABLISHMENTS BY EMPLOYMENT SIZE, FABRICATING INDUSTRIES, 1958

Industry	All establishments	Establishments with designated number of employees									
		1–4	5–9	10–19	20–49	50–99	100–249	250–499	500–999	1,000–2,499	2,500 and over
Fabricated metal products:											
Number of establishments	24,782	7,941	4,177	4,352	4,246	1,892	1,375	480	231	74	14
All employees:											
Number	1,057,986	16,411	28,195	60,118	131,673	130,475	213,475	164,892	156,642	97,868	58,237
Payroll ($1,000)	5,412,405	63,893	123,758	280,572	639,828	646,214	1,084,502	865,117	848,692	536,796	323,033
Capital expenditures ($1,000)	458,397	16,180	14,097	29,539	56,742	45,103	86,265	74,002	66,306	44,611	25,552
Machinery:											
Number of establishments	29,839	12,088	5,634	4,757	3,817	1,458	1,106	478	292	155	54
All employees:											
Number	1,348,245	24,044	37,820	65,037	116,508	101,215	170,433	165,512	202,865	232,498	232,313
Payroll ($1,000)	7,303,661	102,623	184,115	339,438	640,825	544,947	919,037	889,142	1,092,963	1,299,391	1,291,180
Capital expenditures ($1,000)	676,419	47,819	24,101	30,564	52,986	41,086	58,003	62,167	100,312	108,472	150,909
Electrical machinery:											
Number of establishments	8,091	2,103	1,077	1,112	1,293	820	754	446	247	179	60
All employees:											
Number	1,122,284	4,405	7,282	15,617	41,332	57,606	118,012	153,314	172,520	271,565	280,631
Payroll ($1,000)	5,605,985	17,130	30,494	69,049	180,536	255,964	540,729	703,126	840,379	1,390,059	1,578,519
Capital expenditures ($1,000)	449,925	4,367	4,446	7,910	18,690	16,437	45,987	50,884	80,930	102,305	118,019
Transportation equipment:											
Number of establishments	6,607	2,099	923	923	1,001	528	450	225	156	168	134
All employees:											
Number	1,557,759	4,218	6,203	12,844	31,249	36,621	70,716	78,310	112,692	270,175	934,731
Payroll ($1,000)	9,164,581	16,017	26,355	58,184	150,676	180,473	358,824	419,240	631,947	1,588,252	5,734,613
Capital expenditures ($1,000)	608,273	5,131	4,617	5,464	15,836	12,367	21,932	29,809	41,712	168,148	303,257
Instruments:											
Number of establishments	3,526	1,297	554	482	514	258	209	103	68	33	18
All employees:											
Number	296,558	2,685	3,704	6,624	16,390	17,869	32,858	35,952	41,743	47,018	91,715
Payroll ($1,000)	1,578,481	10,083	16,186	29,983	74,924	84,477	156,682	181,123	214,053	244,978	565,992
Capital expenditures ($1,000)	123,621	1,690	1,537	3,364	4,181	5,449	8,122	11,819	15,488	22,265	49,706
Miscellaneous manufacturers:											
Number of establishments	14,273	6,087	2,469	2,111	1,962	814	524	163	74	47	22
All employees:											
Number	571,434	11,972	16,491	28,912	60,704	55,946	80,508	56,317	48,270	69,451	142,863
Payroll ($1,000)	2,847,330	40,058	60,093	107,982	233,729	217,072	328,981	242,614	231,809	368,338	1,016,654
Capital expenditures ($1,000)	183,231	10,640	8,218	9,734	16,387	11,940	20,481	15,279	12,472	22,812	55,268

SOURCE: U.S. Dept. of Commerce, Bureau of the Census, *1958 Census of Manufactures*, vol. 1, table 3, pp. 2-4, 2-5.

TABLE 12. MACHINE SHOPS AND TOOL AND DIE SHOPS IN FABRICATING INDUSTRIES, 1958

Industry group	Distribution by number of production workers in shop							
	Establishments				Employment			
	Total	Number of production workers			Total	Number of production workers		
		1–4	5–19	20 or more		1–4	5–19	20 or more
Machine shops:[1]								
Fabricated metal products	3,199	1,196	1,234	769	77,466	(D)	(D)	60,927
Machinery	7,636	1,705	3,323	2,601	314,947	(D)	(D)	>10,000
Engines and turbines	92	10	9	73	20,883	22	118	20,743
Farm machinery	418	155	154	109	17,176	373	1,564	15,239
Construction equipment	793	172	279	342	36,833	399	2,870	33,564
Metalworking machinery	1,420	222	593	605	63,849	568	6,493	56,788
Metal cutting tools	204	9	59	136	17,393	30	699	16,664
Metal forming tools	136	13	42	81	8,777	34	559	8,184
Special dies and tools	726	161	378	187	13,212	412	3,898	8,902
Machine tool accessories	228	23	85	120	12,996	50	1,030	11,916
Machinery, n.e.c[2]	126	16	29	81	11,471	42	307	11,122
Special industrial machinery	1,125	205	450	470	52,690	521	4,661	47,508
General industrial machinery	876	205	300	371	37,676	494	(D)	>10,000
Office machines	144	34	45	65	7,467	78	418	6,971
Service industry machines	288	103	105	80	14,155	(D)	(D)	12,888
Machine shops	2,480	599	1,388	493	64,218	1,747	13,132	49,339
Electrical machinery	1,802	589	641	572	47,873	1,385	6,448	40,040
Transportation equipment	1,508	297	469	742	165,768	667	(D)	>10,000
Instruments	366	82	127	157	14,930	191	1,380	13,359
Tool and die shops (operated separately from machine shops):[3]								
Fabricated metal products	1,936	1,008	707	221	27,097	2,296	6,394	18,407
Machinery	3,100	1,071	1,261	768	58,561	2,425	12,686	43,450
Electrical machinery	1,016	433	375	208	17,388	(D)	3,653	>10,000
Transportation equipment	745	213	244	288	49,532	470	2,329	46,733
Instruments	195	78	76	41	2,965	170	786	2,009

(D) Withheld to avoid disclosing figures of individual companies.
SOURCE:
[1] U.S. Department of Commerce, Bureau of the Census, 1958. *Census of Manufactures*, vol. 1, table 1, pp. 8–16 to 8–18.
[2] Not elsewhere classified
[3] *Ibid*, pp. 8–18 to 8–20.

clude automation will modulate diffusion of NC techniques. Changes in materials, product lines, and manufacturing methods in a technological society, however, will necessitate a constant reevaluation of the amenability of the manufacturing process to NC techniques.

b. *The economic feasibility of NC conversion*

Potential diffusion of NC machines among the plants listed in tables 11 and 12 is partially dependent upon the size of the plant and partially on the nature of the plant's production. Of the 87,118 plants listed in table 11, nearly 70 percent have fewer than 20 employees. The plants with 20 or more employees, however, account for 94 percent of the employment and the major share of capital expenditures. The same pattern generally holds true for the machine shops listed in table 12.

In plants which are labor-intensive, a pressure to automate will develop. In small plants, the pressure will arise from the necessity to be competitive through greater rationalization and increased production rather than through labor-savings. The number of workers in the small plants may represent the minimum required to conduct the required operations, the employment level representing a part of the basic overhead structure.

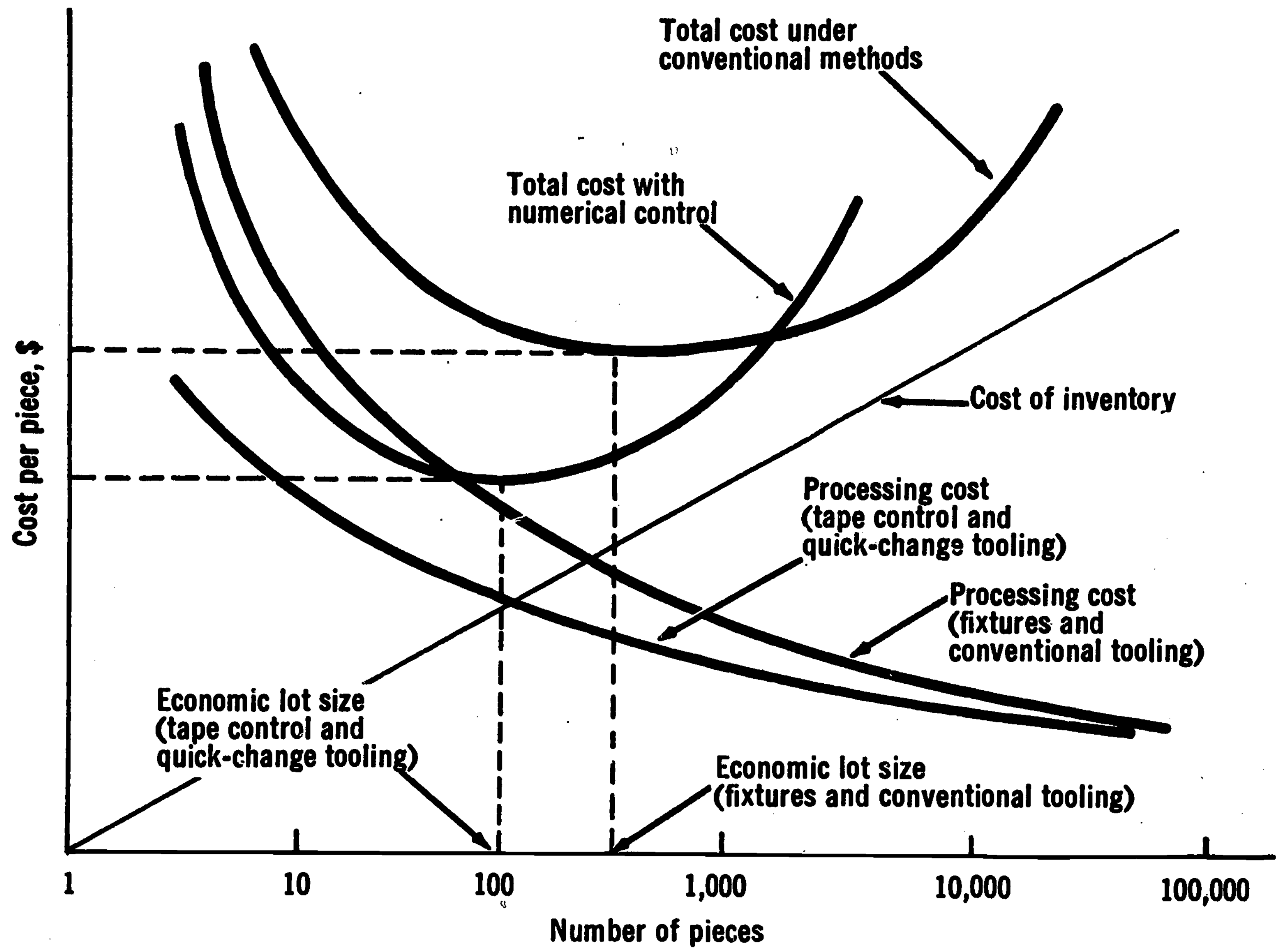
In larger plants, concentration of labor may be in those areas least amenable to automation, as in materials transfer, assembly, etc. A lower bound on employment may thus exist in the small and large plants which automation cannot affect.

In addition to the type of product and the processes by which it is fabricated, the amenability of NC machines is determined by the lot size of the product. From an economic viewpoint, NC machines are used to best advantage in small-lot production. In this respect, NC differs from most automation processes which require mass production to justify economic feasibility.

Figure 3 is a graphic comparison of production costs with NC and conventional tooling as a function of lot size.[9] Crossover points between conventional and NC tooling for long runs are dependent upon the tooling, programing, setup, and machining costs. The graph shows how economic lot size is affected by a reduction in setup time. With tape control replacing fixtures, the cost of small runs is reduced. Simple jobs which involve the drilling and tapping of a few holes, for example, that can be programed and set up in a short period of time, can often be performed more economically with NC machines than conventional methods for even two or three pieces.

[9] *Numerical Control in Manufacturing*, ed., F. W. Wilson, ch. 10, p. 279.

FIGURE 3. *Economic Lot-Size Comparison Tape Control vs. Conventional Tooling*



Source: *Numerical Control in Manufacturing*, McGraw-Hill Book Co., New York, 1963.

For point-to-point jobs in which programing and tool setting are more extensive, 5 to 10 parts may be the breakeven point for NC. NC may be more economical, however, for even one or two complex pieces that use contour machining.

The upper economic lot size for NC machines is around 100 pieces. Accuracy and reliability requirements and machining complexity may sometimes extend the economic lot size to several hundred pieces on NC machines.

Metalworking magazine has listed 15 cases where it is economically advantageous to utilize NC machines: [10]

1. On shortrun work that would not justify the cost of making jigs or fixtures.
2. On jobs that require a large investment in tooling to hold size, shape, or uniformity.
3. On work where leadtime is important for competitive or other reasons.
4. On jobs that have long setup times relative to production time, resulting in low machine and operator productivity.
5. On parts that must be machined at numerous locations or in an intricate pattern of points.
6. On work that calls for a large number of tool changes for various hole sizes or operations.
7. On parts that are processed in a series of operations on separate machines.
8. On work where dimensional relationships must be held from reference points or surfaces.
9. On families of parts where machining operations are similar but not identical.
10. On parts to be assembled by aligning holes, mating surfaces, selective fit, etc.
11. On jobs that require frequent or extensive inspection to check machining accuracy.
12. On work fabricated from high-cost materials or having a high labor content where scrap would be costly.
13. On complex parts that would require a design compromise for the sake of producibility.

[10] "NC—The Time to Act is Now," *Metalworking*, June 1964, pp. 33–39.

14. In prototype or development work where several design changes are likely.
15. On one-shot, few-of-a-kind jobs involving extensive layout or costly and slow toolroom machining.

NC is not only a revolution in machine equipment but is bringing in its wake a revolution in product design, materials handling, production control, purchasing, and cost analysis. To achieve the benefits which NC can provide, the machines must be scientifically scheduled, noncutting time reduced to a minimum, and tool changing made as rapid as possible. Considering that under conventional machining methods the average machine tool is actually machining only 25 percent of the time, the production scheduling required to keep an NC machine operating about 80 percent of the time necessitates a radical departure in machine shop habits.

The average small-production establishment that has not mastered the problems of efficient production scheduling and a realistic costing of its products will, it has been suggested, only turn out scrap faster and more efficiently.

The present pattern of manufacturing and the necessity, on the part of management, to become retrained and oriented in the direction of automatic fabrication techniques will serve as a constraint on the rapid diffusion of NC over the diverse fields of manufacturing. The effects of companies that introduce NC machines on those that do not convert will exert a competitive force leading to a dynamic situation in which economic feasibility and managerial decisionmaking will have to be constantly reevaluated.

In addition to the inertia of traditional methods, the leadtime required to obtain NC machines, install them in plants, and train personnel to operate, program, and maintain them will serve to spread the diffusion of NC over a period of time.

Another of the critical constraints that will determine the rate of diffusion of NC is the capital investment that will be required. The manufacturing plant in the United States is characterized to a large extent by age and a high degree of obsolescence. The average age of metalworking equipment has been rising and, whereas in 1945, 40 percent of machine tools and presses were more than 10 years old, by 1963, 64 percent were in this category. Approximately 10 percent of the tools were more than 20 years old.

American Machinist magazine's inventory of machine tools (1963) revealed that 1.36 million out of 2.14 million metal-cutting machine tools were 10 or more years old.[11] Fifty-seven percent of those more than 10 years old were in four categories—drilling, milling, boring machines, and lathes, the four main types of NC machines. Within the six fabricating industries, the distribution of 10-year or over metal-cutting machines in these four categories is shown in table 13.

TABLE 13. DISTRIBUTION OF DRILLING, MILLING, BORING MACHINES, AND LATHES IN FABRICATING INDUSTRIES, 1963

Industry	Machine tools, all ages		Machine tools, 10 years and over		
	Number	Percent of total	Number	Percent of total	Percent of industry total
All metalworking industries	1,210,291	100	782,514	100	65
Fabricated metal products	212,203	18	140,929	18	66
Machinery	483,048	40	323,408	41	67
Electrical machinery	144,902	12	77,424	10	53
Transportation equipment	190,560	16	127,154	16	67
Instruments	68,745	6	39,308	5	57
Miscellaneous manufacturing	24,597	2	14,791	2	60

SOURCE: *American Machinist*. June 10, 1963.

The American Economic Foundation estimated that metalworking obsolescent plant capacity in 1963 amounted to $95 billion.[12] This situation indicates the inertial force that must be overcome in renovating the manufacturing establishment. At the same time, NC machines present both a challenge and an opportunity to renovate with highly productive and automatic equipment. The economic magnitude of the renovation was suggested in a paper submitted in 1960 to the congressional Subcommittee on Automation and Energy Resources which estimated that one-half trillion dollars would be required to automate the manufacturing industry at 1960 levels of automation. In 1958, $8 billion was spent on capital formation over and above that necessary for replacement and keeping up with population growth. At that rate more than 60 years would be required to raise manufacturing technology to the 1960 level.[13]

Both the rate of capital formation and technological development have changed since 1958–60. However, the magnitude of the economic costs and competing demands for allocation of funds and resources will undoubtedly serve as constraints on a precipitous diffusion of NC machines.

3. *The worker*. The diffusion rate of a technology is a function of other factors in addition to engineering, production, and economic factors. The technology is embedded in a social system in which economic values must often compete with other values, and the allocation of resources and manpower has many contending claimants.

The factory, too, is a social system as well as a production system. The attitudes and responses

[11] *American Machinist*, June 10, 1963.

[12] Cited in "Why We Must Lift Deadweight From Economy," *Metalworking*, 20 (4), April 1964, pp. A2–A7.

[13] Cited by J. Harrington, Jr., "A Look Into Tomorrow," in *New Views on Automation*, papers submitted to the Subcommittee on Automation and Energy Resources, Joint Economic Committee, Washington, D.C., 1960, p. 44.

of the workers as expressed individually and collectively through unions will serve as constraints on the diffusion of NC. Worker satisfaction, occupational status, the problems involved in the changing requirements for skills, and seniority are real and vital problems to millions of workers. The unions, especially, are closely attuned to the problems arising from the intersection of the socioeconomic factors and the social factors in automation. Occupational retraining and attrition can serve as only partial answers to disemployment. They will not generate new employment opportunities for all the displaced.

The Takeoff Stage. Given the pattern of NC diffusion during the past 11 years and considering the constraints discussed in the preceding section, our task is to estimate NC diffusion during the next decade. Let us first consider NC growth in terms of the diffusion model described above.

The four stages of this model, it is recalled, are (1) pretechnology; (2) transition; (3) takeoff; and (4) maturity. For NC, the first stage, which saw the development of the technology, its emergence from the laboratory to the production line, and the proving of its technical and economic feasibility, may be said to have ended by 1958. The period 1959–65 characterized the transition period during which NC found its way into an expanding number of manufacturing plants, a greater number of applications were found, technical know-how increased, and a knowledge of the potential of NC as a manufacturing process took root.

The period beginning in 1966 will be the start of the takeoff stage of diffusion. Growth will be rapid, as indicated by the 18-month purchasing estimates of industry at the start of this stage. The diffusion, however, will be subject to the constraints previously discussed.

Factors which provide a base for the takeoff stage are cited by the Diebold Group:[14]

1. Equipment is available to perform a variety of jobs at prices the average company can afford to pay.
2. Computer technology has greatly expanded, and computers, operators, and programers are more readily available.
3. Programing has been simplified by the widespread use of APT and other related languages.
4. Related NC services are becoming available. These include:
    a. Production centers that produce a part on NC machines from company drawings.
    b. Service bureaus that transform a drawing into a tape for running on a company's own NC machines.
    c. Data communications that provide direct and fast service between the NC machine user and offsite computer services.

[14] H. E. Klein, "Numerical Control: From Class to Mass Market," *Dun's Review and Modern Industry*, August 1965.

In considering the diffusion model, it is interesting to compare the growth in the number of NC machines with the growth of the number of computers as graphed in figure 4. It is noted that the rate of increase of NC machines is greater than the rate of increase of computers.

If the start of the stage of pretechnology is taken to be the year in which a feasible prototype model was developed, 1944 is established as the starting point of the computer development, and 1953 as the starting point of the NC development. In the first decade of computer technology, 1945–54, 2,675 computers were installed. In the first decade of NC machines, 1954–63, 3,583 machines were installed. An additional 5 years were required for the installed computer inventory to expand to 10,000. It is estimated that only 3 additional years will be required for NC machines to reach the 10,000 mark.

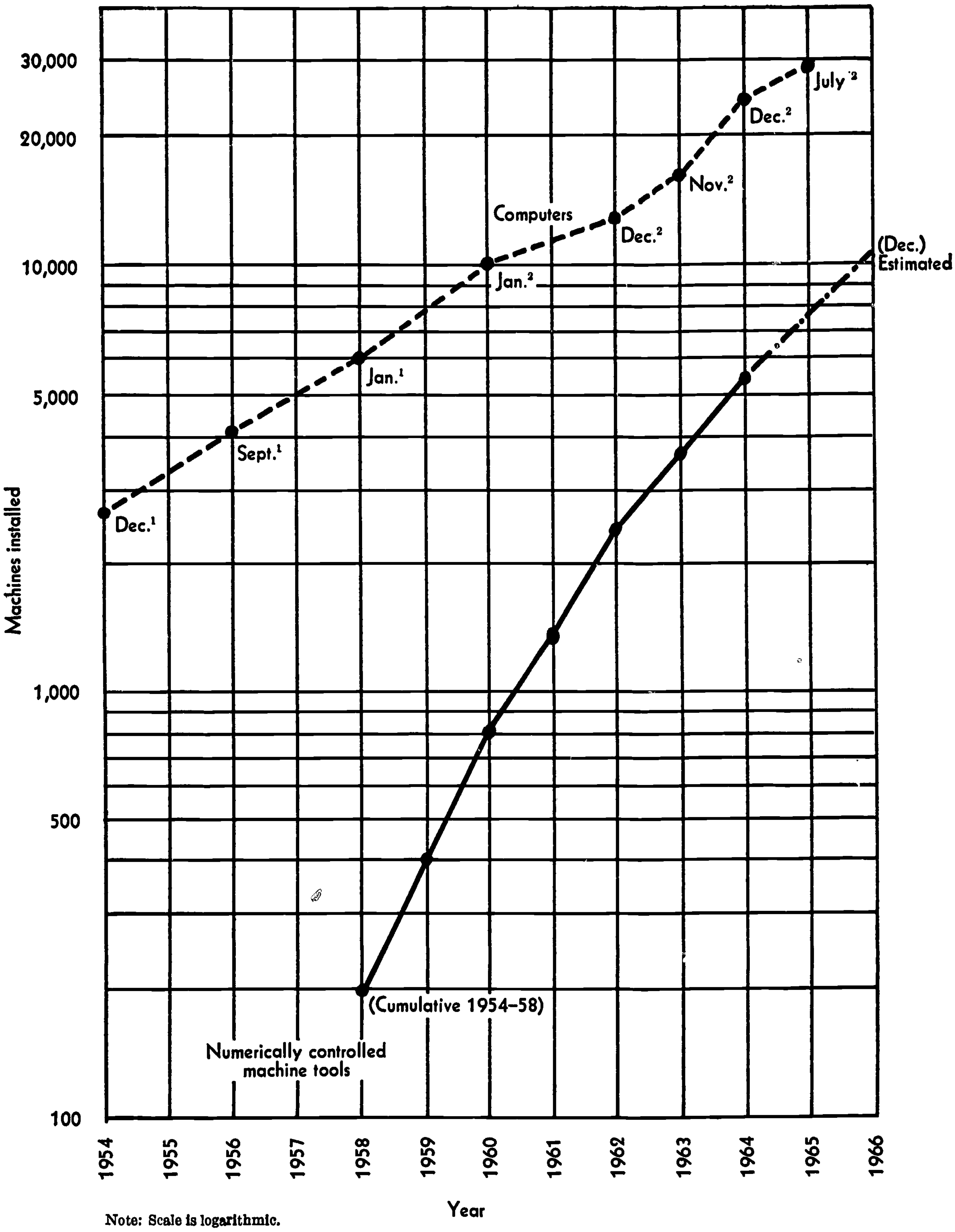
The above comparison should consider a fundamental difference in the diffusion of the two technologies together with a close relationship. The 9-year timelag between the Mark I computer and the MIT numerically controlled milling machine derives from the fact that numerical control is a combination of computer techniques, servomechanisms, and machining. Both the logic and programing techniques developed for computers were utilized in the subsequent development of NC. Continuous path and many point-to-point control systems require a computer for preparation of input tapes or cards.

The difference in the diffusion of the two technologies is significant. In general, computers did not replace other machines but were installed as new equipment, often serving new applications. NC machines, on the other hand, have to be fitted into the framework of the traditional technology, and either replace existing equipment or augment existing production processes. The retrofitting of older machines with NC controls is a realistic problem for management. There was no possibility of retrofitting computers. The implications of this difference in the two technologies will be discussed further in relation to the implications for employment.

The prediction of NC growth figures associated with the takeoff stage is difficult because the future expansion of NC machines is highly dependent upon many factors which are not directly related to NC technology. It is tempting to consider an obsolescence retirement rate at which 10-or-more-year-old machines are replaced annually. This would not provide a satisfactory estimate, however, because the replacement is not on a 1-to-1 ratio. One NC machine, for example, may effectively replace from three to eight conventional machines.

In addition to the future state of the economy, other factors which must enter into consideration

FIGURE 4. *Cumulative Inventory Computers and Numerically Controlled Machine Tools*



Note: Scale is logarithmic.

SOURCES:
[1] Diebold Group Surveys.
[2] Computers and Automation.

in a quantitative forecast of the future of NC machines are the changing mix of machines and the effects of new materials and new processes.

It is observed from table 3 that the average increase in the value of NC machines as a percent of the annual value of shipped metal-cutting machines was 1.86 percent during the period 1959–63. There was a slight drop in 1964 because of the more than $200 million spurt in metal-cutting machine sales. Mid-1965 estimates set the percentage at 17,[15] and the *American Machinist* survey indicated a 22.7-percent value in 1966. The annual value of metal-cutting machines (table 5) displays more variation than the percentage value and is perhaps more susceptible to rapid fluctuation.

Predictions of future growth are dependent, therefore, on two variables: (1) the annual increase in the value of NC machines as a percent of the total metal-cutting machine production, and (2) the value of the annual metal-cutting machine output. The use of NC machines for operations other than metal cutting would not be considered in this projection method, nor would the effects of competing processes and materials. Extrapolation of a curve is always fraught with risk; extrapolation of two variables will not be meaningful enough to warrant projections of absolute figures.

[15] *Automatic Data Processing Newsletter*, The Diebold Group, Inc., May 24, 1965.

4. Technological Trends in Machining, 1965–75

Introduction

The diffusion of numerical control technology is dependent on several additional factors whose implications warrant special consideration inasmuch as they are superimposed on the direct effects of NC technology.

This section discusses some of the technological changes occurring in machining or related fields which alter the need for machining effort. These are concerned chiefly with changes to the material used as the machining stock or the machining tool, and with the effect of competitive processes or materials.

In attempting such an assessment, one is necessarily influenced by current or near current research. For metal cutting, the total world's research effort is very small in both fundamental and applied research. A few centers of outstanding merit exist in other countries, while in the U.S. some universities, independent research organizations, and company-supported laboratories (generally involved in equipment design and process development) are studying several facets of machining. But this amount of effort, when related to the dollars spent for metal removal, is indeed trivial. Technological research cannot solve the sociological problems imposed by new developments; it can only strive to maintain a dynamic balance resisting abrupt changes or else seek to create new industries to offset the decay of the old.

Many new materials and processes have been developed in recent years, and many of the conventional ones have undergone changes. These changes have most often been accomplished to a great extent as a consequence of the need for some unique capability associated with space or defense requirements. Some advances may have very limited applicability beyond that for which they were originally conceived. Others have great commercial significance. Therefore, careful judgment is needed if realistic predictions are to be made of the effect the research developments may eventually have.

The unusual strength of an ausformed steel (in excess of 500,000 p.s.i. tensile strength) does not justify the conclusion that the commercially important carbon steels will be significantly displaced, even though the strength may differ by a factor of eight. Nor can it be assumed that the high initial cost of computers will prevent their applicability for generating input tapes for NC machining. Rather, the ultimate analysis must revolve around the twofold question of, "What unique feature is attained and what will it cost per end item manufactured?"

The Machining Stock

Property Performance of Conventional Materials. Changes in the properties of the material to be machined have a definite influence on the ease with which it can be machined. However, the relationship between machinability and the demand for manpower is not necessarily simple. Ordinarily, increased difficulty of machining implies an increased time requirement and consequently increased manpower. On the other hand, unless the part can be fabricated only by machining because of shape complexity or precision, the increased cost of manufacture may cause substitution of a competitive process, thus displacing a part or all of the machining requirement.

The basic metals of commerce are predominantly iron, steel, aluminum, and copper alloys. During the next decade these will maintain their preeminent position, although the relative proportions will probably shift in the direction of more aluminum tonnage. However, within these categories, changes are being made to the properties attainable, and increased use will be made of these improvements.

In the iron family an unusual annual growth rate of 30 percent has been reached for ductile iron. This material is similar in composition to conventional gray iron except that the free graphite exists as spheroidal rather than flake shapes. The graphite content normally means that the iron will exhibit self-lubrication and easily broken chips during machining, both of which improve the machinability. As a result, the machinability of ductile iron will be nearly equivalent to that of gray iron at similar strength levels.

The unusual feature of ductile iron is that it can develop much higher tensile strength when properly alloyed and subsequently heat treated. Currently values over 100,000 p.s.i. are readily achieved with a distinct probability of more than doubling this strength. An increase in machining effort and time will be required.

Steel also will experience a significant shift toward higher strength compositions. In the case of low-carbon steels modified with small amounts of columbium or vanadium, the moderate strength increases will improve machinability by relieving nose buildup and gummy chip formation; thus machining time will be shortened.

The alloyed high-strength steels will find increasing use, and are very difficult to machine only if used in the hardened condition. Since there is a trend toward greater precision, more machining in the hardened condition is probable. As a counterbalance, free machining additives will be more widely used and extended to some of the higher-strength alloys.

Steels produced to extremely high strength levels by special thermal-mechanical working combinations, such as ausformed steel, are almost impossible to machine by the large chip-forming machining methods. And as strength values are pushed beyond 500,000 p.s.i., only the new metal removal methods are practical. These new procedures as applied to such steels still will use a greater amount of machining time.

Higher strength aluminum compositions also are gaining acceptance, with more improvements on the way. Generally, the aluminum alloys do not exhibit difficult machining behavior, although techniques are different. Higher strength materials handle well, and only compositions containing hard abrasive particles in the metal structure are difficult. Therefore, alloying changes and increased utilization will not significantly alter machining needs.

Copper-base alloys represent a family having excellent machinability. Only a few grades prove to be the exception to this rule. Here again the trend is to greater strength, particularly by using aluminum bronze. This should lead to some increase in the machining effort required.

Unique Properties of Unconventional Materials. The pressure from space and defense needs for performance capabilities well beyond those achieved by the metals predominantly used in commerce has led to a large number of unique materials. All but one of these material innovations has decreased machinability. Machining time and cost is greatly extended for alloys of titanium, as well as the exotic heat resistant alloys containing nickel or cobalt as the base metal, the new refractory metal alloys from tungsten, molybdenum, columbium, tantalum, and hafnium, and the composites of metals, metals and plastics, and metals and ceramics. On the other hand, the new maraging alloys have the capability to be heat treated to very high strength levels, but the hardening heat treatment causes a minimum amount of distortion. Therefore, parts made from this composition can be machined near or to their final dimensions while still in the soft annealed condition. Subsequent hardening can be done without destroying the precision. This ability should decrease machining effort.

The variety and improved performance of plastics will cause displacement of metal from some of its existing markets. Because plastics can be conventionally machined quite readily, increased machining of plastics is anticipated. The manufacture of plastic shapes is simpler than for metal in that pressures and temperatures required in the process are comparatively very moderate. This implies that injection, molding, extrusion, vacuum forming, casting, and similar shaping procedures wil be used generally where production volumes are appropriate.

The Machining Process

New Methods for Removing Metal. New technology will affect the machining process as well as the machining stock, and has already introduced completely new procedures for removing metal. The new processes include electrical discharge machining, electrochemical milling, chemical milling, sonic abrasion, sonic impact, chlorine machining, electron beam, plasma arc, laser beams, etc. The basic concepts employ energy in the form of heat, electricity, chemical reaction, or multiple particle force to accomplish metal attrition. The attack can originate from a point source or be applied in two or three dimensions simultaneously. Electrical discharge machining (EDM) and electrochemical milling (ECM) are examples of the three-dimensional attack and comprise the greatest departure from conventional machining that use pointed cutting tools. EDM and ECM use a conforming electrode shaped in accord with the volume of metal to be removed. As machining proceeds, metal removal occurs wherever the distance between part and electrode becomes sufficiently small. In contrast, laser beam attack is a point source. It is suited to punching holes into or through metal, or if coupled with lateral motion, to shape a three-dimensioned surface. In this respect it is most like conventional machining.

The new processes will grow in importance and number and will not be restricted to the machining of hard metals, or complex parts, or thin metal sections, or unusual geometry. At present, most of these processes are applied to situations where normal metalcutting is not feasible. But the trend toward commercial application has been definitely established. Under these conditions the end cost of the part becomes the dominant criterion, with secondary consideration given to factors such as surface texture, residual stresses, etc.

Chemical milling is widely used in aircraft construction. ECM appears useful as a process for rapidly removing metal, as in rough machining. Both ECM and EDM appear most suited for applications such as the sinking of shaped cavities in tools and dies. A view of these commercial probabilities suggests forecasting a rapidly expanding application for these manufacturing techniques, probably on the order of a twofold increase in the next 5 years and a threefold increase in the next decade. Since much of the expanding market must be found in private industry making capital goods or consumer items, the motivating factor in its use will be cost savings derived principally from reducing the manpower requirement.

Improvements in the Metal Cutting Process. New developments in cutting tools for use on conventional machines are also occurring. In the past, 70 percent of the cutting tool dollar expenditure has been allocated to high-speed steel tools, most of the rest to carbides, and a very small percentage to the old carbon steel and the new ceramic tools. Better high-speed (superhard) steels have been marketed and new ones are under development. Carbide manufacturers are meeting the challenge with better, more uniform performance tools, and ceramics are undergoing vigorous research and will experience a rapid growth rate. In all cases, these advances must be aided and abetted by more powerful and stable machine tools. This too is already happening, so that metal removal rates per cutting tool should increase by 50 to 100 percent during the coming decade. Manhours will be correspondingly decreased.

An additional factor of great import is the establishment under Air Force sponsorship of a Machinability Information Center. This will collect and disseminate to a growing user community information leading to optimization of the machining process. This is an important step which improves the competitive position of the machining process compared to other shaping methods. However, the competitive position will be achieved, in part, by decreasing manpower needs.

Competitive Methods for Shaping Parts. Historically there are many methods for producing a final part to its required configuration. In many instances a combination of processes is used, such as casting, welding, and machining. However, improvements are occurring in several of these methods which will affect the need for machining.

The major processes other than machining include hot- and cold-forging, casting, extrusion, rolling, thread rolling, spin forming, explosive forming, magnetic forming, stamping, coining, and joining by welding or brazing. In general, the precision, surface quality, and internal integrity obtainable by these methods is being greatly improved. Outstanding examples are found in precision forging of turbine blocks, cold-forging of automotive axles, precision casting of forging dies, precision extrusion of aluminum shapes, and diecasting of complex shapes in increasingly high-melting-point metals. Future developments will continue in the same manner and will compound the advantages derived from either the elimination or minimization of machining time. An additional outstanding advantage of some of these methods is the avoidance of waste generation in the form of chips.

It will be observed that most of these manufacturing methods are subject to automation and numerical control. They also require either patterns or dies, most of which are currently formed by machining. Thus, they are more suitable to production where many pieces are required. The dies also comprise a market for machining effort. However, some of this will be offset by use of improved machining methods, such as EDM, and improved processes, such as casting dies essentially to finished shape.

Long-Range Production Equipment Requirements: A Case Study

The effect that changes in materials and machining processes will have in the future are suggested by a detailed study which projects equipment requirements of a specific industry over the next decade. The study was made to project the long-range production equipment requirements of the Air Force through the year 1975.[16] The study analyzed the current production inventory, identified advances being made in the production process, and determined equipment replacements to offset inventory obsolescence over the next 10 years.

The study indicated increased use of high-strength metals and alloys that would necessitate utilization of new processes such as ECM, and a different machine mix. Workpieces of heavier gage and larger size will require ability to "sculpture" from solid stock thus necessitating employment of ECM and EDM machines and emphasizing profiling and traveling column milling machines.

Forming and joining processes for fabricating are estimated to increase while conventional machining will decline. Forming processes which

[16] *Air Force Long-Range Production Equipment Requirements,* Study prepared by Chemical and Metallurgical Research, Inc., for U.S. Air Force Materials Laboratory, Manufacturing Technology Division, Wright-Patterson Air Force Base, Ohio, and summarized in *American Machinist,* 109 (14), July 5, 1965.

TABLE 14. SUMMARY OF REQUIREMENTS FOR MAJOR TYPES OF EQUIPMENT

Category	1964 Inventory		1975 Inventory	
	Number items (in thousands)	Value ($ million)	Number items (in thousands)	Value ($ million)
Material removal	28.5	567	5.9	563
Sheet metal forming	3.3	86	5.3	222
Welding	3.2	16	4.5	160
Electromagnetic test equipment	14.0	45	2.9	138
Mechanical measuring and testing	9.2	69	10.0	133
Heat-treat furnaces	2.2	40	1.6	33
Total	60.4	823	30.2	1,249

SOURCE: Air Force Long-Range Production Equipment Requirements, Study prepared by Chemical and Metallurgical Research, Inc., for U.S. Air Force Materials Laboratory, Manufacturing Technology Division, Wright-Patterson Air Force Base, Ohio, and summarized in *American Machinist*, 109, (14), July 5, 1965.

comprised 23 percent of the 1964 production cost of aerospace systems are expected to increase to 35 percent of the 1975 cost. Machining processes are estimated to drop to 37 percent of the 1975 cost from their 1964 level of 64 percent. Welding and brazing will rise from 13 to 28 percent of total cost.

In contrasting the present inventory with the 1975 projected inventory, it was estimated that the total number of machines will drop 50 percent while their value will increase 50 percent. Estimates of the changed machine-process mix for major types of equipment are shown in table 14.

The projected inventory of material-removal equipment in table 15 shows how the nearly 80 percent decrease in conventional machine tools will be achieved. It is noted that the value of the 28,493 machine inventory of 1964 is nearly identical with the value of the 5,876 machines projected for 1975.

The above case study is a confirmation of the effects the changes in materials and processes discussed in this section will have in the future. The industry studied is unique in its requirements, and these changes will not be necessarily felt in like measure in all industries.

Implications for Manpower Requirements

The long-term trends in the machining industry are to improve attainable precision and reduce part costs—two opposing objectives. New developments in the machining stock materials will increase the difficulty of machining more than free-machining developments will decrease it. However, new machining processes, better information, and advances in cutting tools (not to mention the overriding reduction in machine time by automation and numerical control) will reduce the required time to machine a given part. In addition, improvements in competitive shaping

TABLE 15. CURRENT AND FORECAST ACTIVE AIR FORCE INVENTORY OF SELECTED MATERIAL-REMOVAL EQUIPMENT

Machine type	End of fiscal year 1964				End of fiscal year 1975			
	Items		Value		Items		Value	
	Number	Percent	Million	Percent	Number	Percent	Million	Percent
Boring machines	2,499	8.8	$105	18.5	585	10	$58	10.3
Drilling machines	3,745	13.1	37	6.5	590	10	20	3.6
Grinding machines	5,867	20.6	80	14.1	1,162	20	66	11.7
External, cylindrical	1,148	4.0	25	4.4	227	4	13	2.3
Miscellaneous (form)	317	1.1	14	2.5	284	5	35	6.2
Lathes	5,985	21.0	86	15.2	882	15	31	5.5
Milling machines	5,819	20.4	227	40.1	1,789	30	332	59.0
Bed type	776	2.7	33	5.8	228	4	31	5.5
Profiling	786	2.8	107	18.9	1,008	17	285	50.6
Traveling column	60	0.2	11	1.9				
Miscellaneous	4,578	16.1	32	5.6	868	15	56	9.9
Electroerosion machines	166	0.6	2.7	0.5	580	10	52	9.2
Electrodischarge	110	0.4	1.6	0.3	60	1	2.4	0.4
Electrochemical	29	0.1	0.6	0.1	467	8	47	8.3
Total, major types	28,493	100.0	$567	100.0	5,876	100.0	$563	100.0

SOURCE: Air Force Long-Range Production Equipment Requirements, Study prepared by Chemical and Metallurgical Research, Inc., for U.S. Air Force Materials Laboratory, Manufacturing Technology Division, Wright-Patterson Air Force Base, Ohio, and summarized in *American Machinist*, 109, (14), July 5, 1965.

processes will make further inroads on the total national machining effort, although it must be emphasized that machining offers better precision and consistently reproducible surfaces with good esthetic features.

Increasing research on the problems associated with metal removal will improve the competitive position of machining but may not enhance the manpower requirements in that industry.

In summary, it is estimated that the balance between competitive shaping processes will shift away from machining in its conventional way by 5 to 20 percent in the next decade. The relative manpower requirements for machining, neglecting automation induced changes, will decrease by 20 to 60 percent.

The trend direction for a number of technological changes are shown in table 16.

TABLE 16. EFFECT OF SOME TECHNOLOGICAL CHANGES ON MANPOWER REQUIREMENTS IN THE MACHINING INDUSTRY

Increase Manpower Requirement:
- Increased need for higher dimensional precision.
- Use of significantly harder or higher strength alloys.
- Increased demand for machined surfaces for esthetic reasons.
- More versatile machine tools.
- Enlarged need for plastic shaping and metalworking dies.
- Introduction of composite materials.
- Use of metals more abrasive to cutting tools.
- Consumer demand for more options in the product.
- Increased ability to machine large parts.

Decrease Manpower Requirement:
- Application of numerical controlled machining.
- Advance of competitive shaping technologies.
- Improved precision of other processes.
- Introduction of new metalworking processes.
- Growth of chipless machining methods.
- Replacement of metals by plastics.
- Improved metallic and ceramic cutting tools.
- Wider use of free-machining metals.
- Higher speed, more powerful machine tools.
- Need for thin-section machined structures.
- Growth of machining center concept.
- Reduction in the complexity and number of jigs and fixtures.
- Optimum machining practice through information center.
- Better cutting lubricants.

5. Impact of NC on Employment

Employment Review, 1955–64

The decade 1965–75 will witness many changes in the demographic structure and educational levels in the United States. Superimposed upon these changes will be those affected by a rising productivity. It is within this context that the implications of NC on employment are appraised.

Detailed studies of the impact of NC on employment have not been made and general statistics on this subject are not available. Certain insights into the problem can be gained, however, by reviewing productivity and employment/unemployment trends in the manufacturing industries in general and the fabricating industries in particular.

Table 17 lists the index of output per man-hour in the manufacturing industries in the period 1947–64 together with its reciprocal hours per unit of output. The average annual increase for the 18-year period is 2.5 percent. From 1950–54, the average annual increase was 1.8 percent; from 1955–59, 2.5 percent; and 1960–64, 3.1 percent. These 15 years coincide with the advent of the automation era and include the maturation stage of the computer technology and the transition stage of NC.

Employment and unemployment rates for craftsmen and operatives during the period 1947–64 are shown in table 18. Craftsmen are skilled workers (e.g., machinists, tool and die makers, etc.); operatives are semiskilled workers (e.g., machine tool operators, assemblers, etc.). The number of craftsmen increased 1.3 million in the 15-year period beginning in 1950, while their percent of total employment decreased very little. The number of operatives increased by a lesser amount, 0.7 million, but their percent of total employment decreased more markedly, from 20.3 to 18.4 percent.

The unemployment rate of the skilled craftsmen, in general, was slightly lower than that for

TABLE 17. INDEX OF OUTPUT PER MAN-HOUR IN MANUFACTURING INDUSTRIES ANNUAL AVERAGES, 1947–64 (1957–59=100)

Year	Output per man-hour	Hours per unit of output	Year	Output per man-hour	Hours per unit of output
1947	75.1	133.2	1956	95.1	105.2
1948	78.2	127.9	1957	97.8	102.3
1949	81.8	122.3	1958	99.1	101.0
1950	85.1	117.5	1959	103.3	96.8
1951	87.1	114.8	1960	103.8	96.4
1952	88.2	113.4	1961	106.7	93.7
1953	89.5	111.8	1962	112.6	88.8
1954	90.9	110.0	1963	115.4	86.7
1955	96.8	103.3	1964	119.7	83.5

NOTE: Estimates based primarily on establishment data. Output refers to gross national product in 1954 dollars.

SOURCE: *Manpower Report of the President*, March 1965, table G–1, p. 256.

TABLE 18. EMPLOYMENT AND UNEMPLOYMENT RATES, CRAFTSMEN, OPERATIVES, AND KINDRED WORKERS (PERSONS 14 YEARS OF AGE AND OVER, BOTH SEXES), 1947–64

Year	Employed persons (thousands) [1]						Unemployed rates [2]		
	Total	Craftsmen		Operatives		Craftsmen plus operatives	All occupations	Craftsmen	Operatives
		Employed	Percent of total	Employed	Percent of total				
1947	57,843	7,754	13.4	12,247	21.2	20,001	3.6	3.8	5.1
1948	59,307	8,119	13.7	12,396	20.9	20,515	3.4	2.9	4.1
1949	58,489	7,625	13.0	11,780	20.1	19,405	5.5	5.9	8.0
1950	59,648	7,670	12.9	12,146	20.3	19,816	5.0	5.6	6.8
1951	60,854	8,434	13.9	12,623	20.7	21,057	3.0	2.6	4.3
1952	60,989	8,743	14.3	12,352	20.3	21,095	2.7	2.4	3.9
1953	61,778	8,588	13.9	12,747	20.6	21,335	2.5	2.6	3.2
1954	61,160	8,311	13.6	12,253	20.0	20,564	5.0	4.9	7.6
1955	62,997	8,328	13.2	12,762	20.2	21,090	4.0	4.0	5.7
1956	64,928	8,693	13.4	12,816	19.7	21,509	3.8	3.2	5.4
1957	65,016	8,664	13.3	12,530	19.3	21,194	4.3	3.8	6.3
1958	63,966	8,469	13.2	11,441	17.9	19,910	6.8	6.8	10.9
1959	65,581	8,561	13.1	11,858	18.1	20,419	5.5	5.3	7.6
1960	66,681	8,560	12.8	11,986	18.0	20,546	5.6	5.3	8.0
1961	66,796	8,623	12.9	11,762	17.6	20,385	6.7	6.3	9.6
1962	67,846	8,678	12.8	12,041	17.7	20,719	5.6	5.1	7.5
1963	68,809	8,925	13.0	12,506	18.2	21,431	5.7	4.8	7.4
1964	70,357	8,986	12.8	12,924	18.4	21,910	5.2	4.2	6.5

[1] Table A–10, pp. 202–3.
[2] Table A–15, p. 207.

SOURCE: *Manpower Report of the President*, March 1965.

TABLE 19. WORKERS EMPLOYED AND RATIO OF NONPRODUCTION WORKERS TO TOTAL WORKERS IN FABRICATING INDUSTRIES, 1955–64

Year	Fabricated metal products				Machinery				Electrical equipment			
	Employees (in thousands)			Ratio (percent) [4]	Employees (in thousands)			Ratio (percent) [4]	Employees (in thousands)			Ratio (percent) [4]
	Production [1]	Nonproduction [2]	Total [3]		Production [1]	Nonproduction [2]	Total [3]		Production [1]	Nonproduction [2]	Total [3]	
1955	897.8	224	1,122.4	20.0	1,069.2	380	1,448.5	26.2	924.2	317	1,240.8	25.5
1956	900.7	239	1,140.4	21.0	1,158.5	413	1,571.6	26.3	975.4	348	1,323.1	26.3
1957	913.2	254	1,167.3	21.8	1,143.1	443	1,585.9	27.9	958.7	385	1,343.8	28.6
1958	824.5	252	1,076.9	23.4	945.5	416	1,362.4	30.5	857.3	392	1,249.0	31.4
1959	868.5	254	1,122.5	22.6	1,027.2	425	1,452.1	29.3	969.4	427	1,396.4	30.6
1960	874.3	261	1,135.3	23.0	1,035.9	443	1,479.0	30.0	996.3	471	1,467.1	32.1
1961	826.0	259	1,084.5	23.9	967.4	444	1,418.6	31.2	979.4	494	1,473.3	33.5
1962	863.7	264	1,127.5	23.4	1,037.8	455	1,493.2	30.5	1,051.5	517	1,568.3	33.0
1963	883.7	269	1,152.7	23.3	1,058.7	473	1,531.3	30.9	1,036.6	520	1,556.6	33.4
1964	920.9	276	1,197.0	23.1	1,121.1	491	1,611.9	30.4	1,039.6	509	1,548.7	32.8

Year	Transportation equipment				Instruments				Miscellaneous manufacturing			
	Employees (in thousands)			Ratio (percent) [4]	Employees (in thousands)			Ratio (percent) [4]	Employees (in thousands)			Ratio (percent) [4]
	Production [1]	Nonproduction [2]	Total [3]		Production [1]	Nonproduction [2]	Total [3]		Production [1]	Nonproduction [2]	Total [3]	
1955	1,414.1	441	1,854.6	23.8	229.6	93	323.2	28.8	330.4	66	396.2	16.7
1956	1,364.3	489	1,852.5	26.4	236.1	102	337.8	30.2	333.1	70	403.0	17.4
1957	1,395.0	514	1,909.1	26.9	233.1	109	342.1	31.9	315.3	72	387.2	18.6
1958	1,128.2	479	1,607.3	29.8	214.8	109	323.8	33.6	299.5	73	373.0	19.6
1959	1,175.7	486	1,661.9	29.2	230.3	115	345.3	33.3	312.9	75	387.7	19.3
1960	1,114.7	472	1,586.7	29.7	232.6	121	354.3	34.2	314.3	76	389.9	19.5
1961	996.5	462	1,458.0	31.7	223.1	124	347.4	35.7	303.5	74	378.2	19.6
1962	1,061.1	482	1,542.6	31.2	229.1	130	358.7	36.1	313.2	76	389.6	19.6
1963	1,112.8	496	1,609.3	30.9	232.2	132	364.7	36.3	311.0	76	387.4	19.7
1964	1,131.3	489	1,620.5	30.2	233.6	135	369.0	36.7	320.2	80	399.8	19.9

[1] Table C–2, p. 234.
[2] Table C–3, p. 235.
[3] Table C–1, p. 233.
[4] Table C–3, p. 235.

SOURCE: *Manpower Report of the President*, March 1965.

all occupations. The unemployment rate of the semiskilled operative has been consistently higher than that for all occupations, and 30 to 60 percent higher than for craftsmen.

The Korean war and the recessions of 1954, 1958, and 1961 have caused major variations in the figures of the output index and employment/unemployment table, making it difficult to note the contributory effects of a specific technology.

A more detailed analysis of employment in the six fabricating industries is given in table 19 for the period 1955–64. This is essentially the transition period for the diffusion of the NC technology. The effects of other automation technologies (e.g., Detroit automation, automatic assembly, etc.) are also blended in so that a separation of the effect of the diverse technologies cannot be estimated. In addition to the gains in productivity arising from automation there are those resulting from gradual, progressive improvements in manufacturing methods and management practices.

In the 10-year period, there was an increase of 75,000 employees in the fabricated metal products industries, which had a total employment of nearly 1.2 million in 1964. More than two-thirds of this increase was in the category of nonproduction workers, a category which rose from 20 to 23.1 percent of the total employment in the industry group.

The machinery industry showed an increase of 163,000 employees, 68 percent of which was in the nonproduction worker category. The ratio of nonproduction workers to total employees in the industry rose in the 10-year period from 26.2 to 30.4 percent.

The largest employment gain among the six industry groups was registered by the electrical equipment industry, which includes the electronics, communications, and computer industries. The 10-year increase of 308,000 employees was distributed 63 to 37 in favor of the nonproduction worker group. The heavy involvement of this industry group in defense-related industries, as discussed earlier should be noted.

A decrease of 234,000 employees is observed in the transportation equipment industry, which includes the automotive and aerospace industries. The number of production workers decreased by 283,000, while an increase of 38,000 nonproduction employees raised the ratio of nonproduction workers to total employment from 23.8 to 30.2 percent.

The instruments industry showed a net increase of nearly 46,000 workers, 42,000 of whom were in the category of nonproduction workers. The miscellaneous manufacturing industries registered a net increase of only 3,600 employees in 10 years. Production workers declined by more than 10,000, while nonproduction workers increased close to 14,000. The increasing ratio of nonproduction workers to total employees was evidenced in both these industry groups.

A summary of the changing employment figures and the ratio of nonproduction workers to total employees in the six fabricating industries is shown in table 20. Total employment increased by 361,000 workers in 10 years. The increase, however, was totally in the category of nonproduction workers, which grew by 495,000 employees. Production workers, on the other hand, decreased by nearly 100,000. The ratio increased from 23.8 percent in 1955 to 29.3 percent in 1964, a rise of 23 percent in 10 years.

The gradual increase in the ratio of nonproduction workers to total employment is evidence of the occupational shift occurring in industry. Increasing rationalization and automation continue the process of shifting decisionmaking to higher educated and more technically qualified personnel while at the same time turning routine operations over to machines. Whether significant or not, it is noted that beginning in 1961, in the six industry total and in four of the six industry groups, there was a reversal in the ratio, and between 1961 and 1964 a small decrease was registered.

Employment Implications of NC

Distinct categories of industries should be considered in assessing the effects of NC on general employment. These include (1) the NC machine manufacturing industry, (2) the manufacturers of auxiliary equipment required for NC, such as controls and computers, and (3) the user community. This distinction will help to avoid misleading analogies with horse-and-buggy workers becoming auto workers or the development of a completely new computer industry.

TABLE 20. TOTAL EMPLOYMENT AND RATIO OF NONPRODUCTION WORKERS TO TOTAL WORKERS IN SIX FABRICATING INDUSTRIES, 1955–64

Year	Production workers (in thousands)	Nonproduction workers (in thousands)	Total employment (in thousands)	Ratio (percent)
1955	4,865.3	1,521	6,385.7	23.8
1956	4,968.1	1,661	6,628.4	25.0
1957	4,958.4	1,777	6,735.4	26.3
1958	4,269.8	1,721	5,992.4	28.7
1959	4,584.0	1,782	6,365.9	27.9
1960	4,568.1	1,844	6,412.3	28.7
1961	4,295.9	1,857	6,152.9	30.1
1962	4,556.4	1,924	6,480.4	29.6
1963	4,635.0	1,966	6,601.0	29.7
1964	4,766.7	1,980	6,746.7	29.3

1. The NC machine manufacturing industry. NC machine manufacturing will not lead to the rise of a completely new industry as happened with computers. The machine tool industry is an old and established industry and the production of NC machines is replacing the production of conventional machines. In addition, the machine tool industry is one of its own best customers, and over 13 percent of the NC machines produced in the period ending in 1963 were used in the production of new machines. The expected purchase of 42 percent NC machines of the total metal cutting investment by this industry in the 18-month period ending December 1966 will accelerate the trend towards automating its own facilities. Similarly, the analogy to horse-and-buggy workers becoming auto workers is not appropriate, because the machine tool industry is in the position of the auto industry of 1955, not the buggy industry of the turn of the century. The number of auto workers is being reduced while the output of essentially the same product is rapidly increasing.

As the number of NC machines produced increases, the total number of all types of machines will be reduced because of the 3:1 to 8:1 displacement ratio. As a result the number of workers required to produce fewer machines with more automatic equipment will tend to decrease. The differential in value of the new mix of machines produced compared to conventional machines may not be large, however, because of the greater cost of NC machines.

2. Manufacturers of auxiliary equipment. There will be created an increasing demand for the electronic controls, sensors, transducers, and servomechanisms needed for NC machines. To a large extent, these auxiliary devices are today produced by other companies that produce them for the NC machine manufacturers. With the growth of NC technology, some of the auxiliary controls will be produced by the machine manufacturers or, in some cases, as in the aerospace industries, by the ultimate user. Because controls have comprised nearly 30 percent of the total NC product value, the rising demand and its implications for increased employment can be significant.

The largest users of NC machines usually have their own computers. Smaller and newer users of NC machines will tend to purchase a computer for general use and use it part of the time for NC functions. Those who cannot justify a computer only for NC functions will have increasing opportunity to utilize general service bureaus and specialized NC computer centers. Thus, a distinctive rise in computer demand stemming from NC requirements is not anticipated.

3. The user community. As previously suggested in the discussion of the manufacturing user community, the effects of NC will be both industry and labor selective. That is, NC will have a differential effect upon the various industries and strata of workers in these industries. The most far reaching effects will continue to be experienced in the aerospace and machinery manufacturing groups. As NC becomes more widespread in nonmachining tasks, such as wire wrapping and batch fabrication processes, for example, it will spread rapidly, especially in the electronics industries.

The effects of NC on the automotive industry will become significant within the next few years. The most time consuming and expensive part of model changes has been the extensive lead time required to design the models and prepare tools and dies. With the use of NC machines, diemaking has become a faster and simpler process. It is reported that nearly all new die-milling machines purchased by the auto industry are either NC or NC-adaptable.[17]

The use of automatic drafting machines and computer-aided design techniques is estimated to have cut 9 months from the 21 traditionally required to go from a clay model to a body press. With NC machines for the cutting of dies and making body templates, the present lead time of 28 to 30 months for a model change can now be reduced to 18 months. Within 2 to 3 years it is expected that this can be further reduced to 10 to 12 months.

Because one of the chief motivations for replacing conventional machines by NC machines is the saving in labor costs, and because one NC machine can effectively replace several of the conventional machines, the number of workers directly employed on the NC machines will decrease. Further, one operator can often control two or more NC machines. The greater design freedom afforded by NC methods and the greater accuracy and reliability that can be achieved will also tend to reduce the number of workers required for assembly, testing, inspection, and quality control. The number of maintenance personnel required to service complex NC systems may not be greater than presently required. Requirements for draftsmen will decline as computer-aided design techniques and automatic drafting machines gradually take over many of the draftsman's functions.

In contrast to the job-decreasing factors, there is a compensating factor in the need for NC programers. It is doubted, however, that the demand for programers will take up the slack arising from displaced production workers. Several developments also suggest that the role of the programer may be reduced. The use of the APT, ADAPT, and other NC-oriented computer languages reduces the necessity for a programer to prepare a tape in machine language. Hence the output of a programer is greatly increased through the use of an English-language type control language. Pressure will grow on computer manufacturers to provide prepared NC programs on various size computers. This, coupled with the development of NC service centers, will tend to prevent the growth of large NC programer staffs.

Of greater importance in the future are the computer-aided design techniques which may, in large measure, bypass the part programer and directly produce an NC tape from an internally stored design placed in a computer by a design engineer drawing lines on the screen of a graphics console.

The economic competition generated by the full utilization of NC technology will have its effect upon the small and inefficient machine shop, tool and die shop, and manufacturing plant. Already the existence of machining centers which are based entirely on the NC technology are in competition with conventional shops. Larger firms, too, for purposes of both economy and better utilization of capital and other resources, will look closely at consolidation of plants. Other structural changes in manufacturing may also develop from extensive use of the NC technology.

Employment, 1965–75

The labor force (individuals 14–64 years of age) is expected to increase from nearly 77 million in 1964 to 93.6 million in 1975. Increases of more than 4 million will occur in the male age group 20–24 years, 3.5 million in the male 25–44 year group, and nearly 2 million in the 45–64 year group. The number of female workers in the last two age groups is expected to remain relatively constant at more than 9 million for the 25–44 year group and 11.7 million for the 45–64 year group.

This labor force will be better educated than the present labor force. Whereas 46.2 percent of the nearly 60 million civilians 25 years of age and over in 1964 had attended less than 4 years of high school, 38.5 percent of the 70 million over-25 labor force will be in this category in 1975. Those with 4 or more years of high school will increase from 53.8 percent of the smaller labor force to 61.5 percent of the larger labor force. Those with only an elementary school education are expected to decline from 14 to 8.8 percent.

The Department of Labor projects employment in the manufacturing industries to reach 20 million workers by 1975, an increase of 20 percent from 1960. Employment growth in the electrical equipment and instruments industries is expected to be more rapid than in the other durable goods and fabricating industries. Employment projections by major occupational groups are shown in table 21. The number of skilled workers (craftsmen) is expected to increase, although their percent of the total employment will remain constant. The

[17] *Business Week*, Sept. 11, 1965.

TABLE 21. EMPLOYMENT BY MAJOR OCCUPATIONAL GROUP, 1960–75

Occupational group	1960 (actual)		1970 (projected)		1975 (projected)	
	Number (in millions)	Percent	Number (in millions)	Percent	Number (in millions)	Percent
Professional	7.5	11.2	10.7	13.3	12.4	14.2
Craftsmen (skilled)	8.6	12.8	10.3	12.8	11.2	12.8
Operatives (semiskilled)	12.0	18.0	13.6	16.9	14.2	16.3
Laborers (unskilled)	3.7	5.5	3.7	4.6	3.7	4.3
All other	34.9	52.5	42.2	52.4	46.1	52.4
Totals	66.7	100.0	80.5	100.0	87.6	100.0

SOURCE: *Employment Projections by Industry and Occupation, 1960–75*, Special Labor Force Report No. 28, U.S. Department of Labor, Bureau of Labor Statistics.

percent of semiskilled operatives is expected to decrease as is the percent of unskilled laborers. Only in the professional category is an increase in percent of total employment projected.

Those occupational groups that will be most directly affected by the NC technology include 1,120,000 workers (1963), classified as follows:[18]

Machine tool operators (operatives)	570,000
Machinists, layout men, instrument makers (craftsmen)	360,000
Tool- and die-makers (craftsmen)	150,000
Setup men (operatives)	40,000

These workers were distributed among the manufacturing industries as follows:

Machinery	315,000
Transportation	230,000
Automotive	140,000
Aircraft	70,000
Fabricated metal products	220,000
Electrical equipment	135,000
Primary metal	70,000
All other	150,000

How many of them will be disemployed by the entry of NC machines into their industries is dependent upon the complex of factors discussed in this report. Although some disemployment will be compensated for by the approximately 25,000 replacements required annually for retirements and deaths, and some workers will be absorbed by retraining and occupational shifts, the key problem is employment growth.

Another important factor that will weigh heavily upon the impact of NC on employment is the situation in the defense-related industries. In 1963, 9.5 percent of the GNP was devoted to purchases of goods and services for national defense, and 9.3 percent of the total employed labor force was utilized in this production. Four percent of this total, 2,870,000 workers, were in private industry:[19]

Transportation equipment	700,000
Aircraft and parts	585,000
Ship and boat building	85,000
Other transportation equipment	30,000
Electrical equipment and supplies	555,000
Ordnance and accessories	270,000
Other industries	1,345,000

The total value of shipments of products to the Department of Defense in 1963 was nearly $21 billion. The total exceeds $25 billion upon adding shipments to NASA, AEC, and other Government agencies. The distribution of the value of shipments and the number of employees in the defense-related industries is shown in table 22.

Although the percent of total value that goes directly to defense is small in some industries, as in the metalworking, in other industries defense-related shipments comprise the bulk of their production. It is not clear from table 22 whether shipment of an NC machine, for example, to an aerospace industry that will employ it in the production of a missile is considered a defense-related shipment.

An analysis of 34 firms with the largest defense contracts show that defense-related work represented 75 percent or more of total company sales for 7 of these firms, 50 to 74 percent for 10 firms, 25 to 49 percent for 8 firms, and 1 to 24 percent for 9 firms. Defense employment was 10 percent or more of the manufacturing employment in 15 States, ranging as high as 30.3 percent in Kansas and 29.6 in California. Several metropolitan areas were largely engaged in defense work: San Diego, 81.8 percent; Wichita, Kans., 71.7 percent.[20]

Employment in the defense-related industries is almost wholly in facilities built for the production of specialized equipment. Both the specialized equipment, comprising 90 percent of the total defense production, and the machines and processes used in manufacturing, are in large measure the result of heavily funded research and development. R. & D. in the fabricating industries was as shown in table 23 in 1963.

The NC technology will have major impact upon these industries, and their workers will face unemployment in shifts from defense spending and disemployment from adoption of the new technologies. The number of workers involved by occupational classification were (1960):[21]

Skilled workers	268,600
Mechanics and repairmen	78,600
Construction trades	72,500
Metalworking trades	62,300
Other skilled labor	55,200
Operatives	148,400

[18] *Occupational Outlook Handbook 1963–1964*, U.S. Department of Labor, p. 434.

[19] *Report of the Committee on the Economic Impact of Defense and Disarmament*, Washington, D.C., July 1965, table A–3, p. 75.

[20] *Defense Conversion Potential*, Study made for the Department of Defense, Summary report in *New York Times*, Apr. 13, 1964.

[21] *The Economic and Social Consequences of Disarmament*, U.S. Arms Control and Disarmament Agency, March 1962, table 8, p. 44.

TABLE 22. SHIPMENTS AND RECEIPTS OF DEFENSE-ORIENTED INDUSTRIES BY INDUSTRY AND CUSTOMER CATEGORIES, 1963

Industries	Total value of shipments reported	Value of shipments of establishments reporting Government shipments of more than $100,000: Total	Government: Total	Government: Prime contract	Government: Subcontract	Nongovernment	Value of shipments of other establishments	Number of employees of establishments reporting Government shipments of more than $100,000 (thousands)
	Millions of dollars							
All industries: Total	40,315	37,210	25,254	20,030	5,224	11,956	3,105	1,938
Total	6,161	4,763	746	490	256	4,017	1,398	224
Steam engines and turbines	525	518	95	47	48	423	7	25
Construction machinery	2,565	1,727	179	137	42	1,548	838	67
Metal-cutting machine tools	887	590	66	25	41	524	297	35
Metal-forming machine tools	349	176	19	7	12	157	173	10
Computing and related machines	1,835	1,752	387	274	113	1,365	83	87
Total	7,243	7,073	4,879	3,571	1,308	2,194	170	376
Telephone; telegraph apparatus	1,686	1,610	138	114	24	1,472	76	84
Radio, TV, communications equipment	5,557	5,463	4,741	3,457	1,284	722	94	292
Total	3,387	2,577	1,039	276	763	1,538	810	195
Electron tubes, receiving type; Cathode ray picture tubes	542	348	53	22	31	295	194	25
Electron tubes, transmitting	283	277	182	86	96	95	6	19
Semiconductors	610	590	215	23	192	375	20	48
Electronic components	1,952	1,362	589	145	444	773	590	103
Total	15,868	15,777	13,851	11,873	1,978	1,926	91	785
Aircraft and complete guided missiles	9,246	9,208	8,186	7,771	415	1,022	37	449
Aircraft engines and parts	3,811	3,803	3,262	2,536	726	541	8	178
Aircraft propellers and parts; Aircraft equipment	2,811	2,766	2,403	1,566	837	363	45	158
Shipbuilding and repairing and ordnance, except guided missiles	3,060	2,953	2,260	2,085	175	693	107	182
Total	3,431	2,922	1,508	947	561	1,414	509	133
Scientific instruments	1,550	1,415	1.202	718	484	213	135	74
Aircraft engine instruments, except flight; Other mechanical and controlling instruments (including nuclear radiation)	280	200	118	75	43	82	80	14
Optical instruments and lenses; Photographic equipment	1,601	1,307	188	154	34	1,119	294	45
Miscellaneous industries	1,165	1,145	971	788	183	174	20	43

SOURCE: *Report of the Economic Impact of Defense and Disarmament*, Washington, D.C., July 1965.

TABLE 23. FUNDS FOR RESEARCH AND DEVELOPMENT BY INDUSTRY AND SOURCE, 1963

Industry	$ million: Total	$ million: Federal Government	$ million: Company	Federal Government as percent of total
Total	12,723	7,345	5,378	57.7
Fabricated metal products	162	29	133	17.9
Machinery	977	264	713	27.0
Electrical equipment	2,483	1,562	921	62.9
Motor vehicles and equipment	1,103	289	814	26.2
Aircraft and missiles	4,835	4,371	464	90.4
Instruments	497	232	265	46.7

Source: *Report of the Committee on the Economic Impact of Defense and Disarmament*, Washington, D.C., July 1965, table A–17, p. 88.

The vulnerability of workers in the five major defense-related industries (ordnance, SIC 19; communication equipment, SIC 366; electronic components, SIC 367; aircraft, SIC 372; ship building, SIC 373) to the war/peace situation is shown in employment figures. Between 1962 and 1964, for example, employment was down 6.2 percent in these industries, with a drop of nearly 50,000 workers in the aircraft industry alone. A similar decline occurred in the the communication equipment industry. More than 200,000 workers had been laid off since 1962 in 16 of the major defense-producing States.

The cumulative effects of automation in the fabricating industries in which NC technology has only begun to have an impact is indicated by an economic review of the 1955–64 period. At a time when GNP rose from $397.5 billion to $622.3 billion (values in current dollars), and total employment rose from 63 million to more than 70 million, employment in the fabricating industries increased by only 361,000 workers. Thus less than 5 percent of the employment increase was contributed by a group of industries comprising 9.6 percent of the total employment and nearly 31 percent of the total number of craftsmen and operatives. During the 1955–62 period, the contribution of these industries to the total GNP rose from $67.9 billion to $74.1 billion with an increase of only 95,000 workers. Thus a large expansion in the general economy was required for the number of employees in the fabricating industries to remain relatively stable.

The changeover to NC machines is sometimes associated with the changeover to more complex and labor intensive fabrication. This is especially true in the aerospace industries. The labor component in fabrication of a DC–8 jet plane, for example, is estimated to be four times that of a DC–7 propeller plane. The disemployment arising from NC is therefore masked by the increased labor demand resulting from the more complex engineering design.

Increased design complexity with its resultant need for labor and increased demand, however, need not always be employment creating. One of the motivations for introduction of NC, besides labor savings, is economy of scale, decreasing the cost of production by more intensive and rationalized manufacturing methods. Hence an expanding economy with an increasing product demand will itself generate pressures to install NC machines with their laborsaving potential. This has been the experience of the auto industry in regard to automation. By itself, the NC technology does not appear to hold promise to create jobs and will tend, in the long run, to diminish their number.

PART 2: STATUS AND POTENTIAL OF AUTOMATIC ASSEMBLY

6. Summary and Conclusions

Automatic Assembly Technology

Assembly is a process for combining individual component parts to form a useful product. The process is called subassembly if the product must be further combined to perform its ultimate function; if no further combination is required, it is referred to as final assembly. The two aspects of assembly pose different degrees of technological problems and it is usually the simpler subassembly processes that have been automated.

More than 50 percent of manufacturing cost is attributable to the assembly process. Nevertheless, the mechanical complexity of assembly automation and the relatively high machine costs have made replacement of the human assembler by machine a difficult and expensive task.

Beside the technological complexity of the automatic assembly machine there are four associated problems for which solutions must be found by users before automatic assembly becomes widespread.

(1) For full exploitation of the technology, the product should be designed to some extent for automatic assembly, rather than simply attempting to construct an automatic machine to assemble a product evolved for manual assembly.

(2) Component reliability must be enhanced because a machine cannot adequately replace the senses of an assembly worker in detecting flaws, etc.

(3) Control must be made and maintained over more types of components, especially in relation to part orientation.

(4) Although measurable quality characteristics can be inspected by a machine, it is extremely difficult to inspect and control attributes of quality such as color, surface finish, or general appearance.

The automotive industry has pioneered in the development of automatic assembly techniques and has automated some internal mechanisms and subassemblies but not final assembly. The electronics industry has automated assembly of circuit boards and other standardized modules. Light bulbs, radio tubes, tin cans, safety razors, ball bearings, ball-point pens, portions of cameras, watt-hour meters, and clocks are products which have been automatically assembled.

The products above are usually small, standardized, of stable design, and are produced in very large volumes. Because most assembled products do not satisfy these conditions, they are not presently amenable to automatic assembly.

A fuller utilization of automatic assembly is dependent upon the development of general-purpose machines that will be capable of handling many applications and can be reprogramed. Such machines are visualized as multistation, in-line transfer or rotary machines having a facility providing for the automatic assembly of multiple products through computer control of the stations on the machine.

The economic feasibility of automatic assembly is dependent on high volume production, estimated at a minimum of 500,000 units annually. Labor time and cost is another important consideration. In addition, model design variations, frequency of assembly, stability of product design, and product complexity are factors which enter into a cost analysis.

Economically justifiable automatic assembly now costs about $5,000 to $7,000 per single station on a special-purpose machine for small assemblies. The payback period usually desired and often achieved is 1 to 2 years on a one-shift basis. As development costs go down through increased standardization of assembly equipment, and as users become skilled in designing products for automation, equipment costs for automatic assembly machines can be expected to decrease.

Diffusion in Industry

The Transition Stage. Two techniques have been used to assess the diffusion of automatic assembly technology. One method was to develop a model of technological diffusion and identify the status of automatic assembly in regard to the model. The second technique was to list diffusion constraints and estimate their restraining effects upon the widespread and rapid diffusion of the technology.

Automation is progressing unevenly in the fabricating industries, moving at a rapid pace in machining departments and slowing to a crawl in assembly departments. Assembly continues to be mostly handwork whereas machining and forming operations are being extensively automated.

Automatic assembly, as defined in this report, emerged as a specialized technology in the early 1950's. Because of the many problems associated with the technology, the experience of many early users was not completely satisfactory, and further development languished during the period 1950–60. Both the limits and potentials of automatic assembly came to be better understood, however, in both a technological and an economic sense.

During the past 5 years the development and use of special-purpose automatic assembly machines has indicated a revived interest. The automotive industry is the largest user of automatic assembly techniques, accounting for between 50 to 70 percent of all automatic assembly installations. From 5 to 15 percent is accounted for by the consumer appliance industry, and the remainder by all other industries.

An assessment of the developments in automatic assembly since 1950 in terms of the four-stage diffusion model described in part 1 indicates that the technology has completed the stage of pretechnology and is now in the transition stage. More models of automatic assembly machines are being produced in a varying price range and an increasing number of applications are being found.

The transition period will probably be lengthy in contrast to the short periods experienced by the computer and numerical control technologies. The takeoff stage may not begin until well past 1975 for it is dependent upon development of a flexible, programable assembly machine comparable to the numerically controlled machining center.

Diffusion Constraints. The rate of diffusion is dependent upon the aggregate of decisions which plants make in accordance with the following criteria:

1. Is the technology amenable to the unique circumstances of the individual plant?
2. Is the technology economically feasible; that is, will it result in reduced costs and increased productivity?
3. Can the capital investment required for equipment, retraining, and maintenance be justified and obtained?

Operating in the context of the general economic situation, plants will be influenced in their decisions by diffusion constraints. These constraints are factors which will tend to restrain the growing use of automatic assembly machines and impede their expansion into all areas of the fabricating industries. These constraints appear in the machine industry, the user community, and the worker community.

The number and size of automatic assembly machine manufacturers will be a major limiting factor to substantial growth in the number of automatic assembly installations. The 10 to 12 companies that produce complete assembly systems are generally small (the largest company employs 150 workers) and funds for new product development are limited. These companies are oriented to small volume, custom designed equipment.

Automatic assembly equipment designed and built by the user community could equal or exceed the number of machines built by the assembly equipment manufacturers. About 100 small companies, some with less than 20 workers, supply specialty devices for automatic assembly to both assembly manufacturers and users.

The potential user community is a highly heterogeneous collection of 87,000 manufacturing establishments (1958) varying in size from several to many thousand workers. Nearly 70 percent of the plants employ less than 20 workers, but the remaining 30 percent account for 94 of the total employment and the bulk of the capital expenditures.

Thirty-seven 4-digit SIC code industries, out of 147 in the 6 fabricating industries, are deemed most amenable to automatic assembly. The diffusion of automatic assembly within subgroups of industries and particular establishments will be constrained by the volume of production and in many cases by the number of workers employed. The majority of automation ventures will occur, it is believed, in plants employing 500 or more workers.

Because many of the smaller plants produce specialty products often in volumes below that required for automatic assembly, widespread diffusion of automatic assembly in these plants is not foreseen in the next decade.

The potential market for automatic assembly machines has been estimated at about $250 million. This would imply the production of more than 2,500 machines.

The social and economic implications of automatic assembly as a part of automation confront the workers and the unions with a difficult situation. The struggle over worker satisfaction, occupational status, changing skill requirements, and seniority will serve as constraints in a social system in which economic values must compete with other values in the allocation of resources.

Employment Implications

Employment Review, 1950–64. The cumulative effects of automation in the fabricating industries in which automatic assembly technology has only begun to have an effect can be glimpsed from an economic review of the period 1950–64. This period has coincided with the advent of the automation era and includes the maturation stage of computer technology and the transition stage of numerical control technology.

The average annual increase in the index of output per man-hour, one measure of productivity, was 2.5 percent during this period; 1.8 percent from 1950–54; 2.5 percent from 1955–59; 3.1 percent from 1960–64.

The number of operatives in all industry increased by 0.7 million in the 18-year period beginning in 1947, while their percent of total employment fell from 21.2 to 18.4 percent of total employment. Semiskilled operative unemployment has been consistently higher than for all occupations and 30 to 60 percent higher than for craftsmen.

In the six fabricating industries during the period 1955–64, total employment increased by only 361,000 workers. The increase, however, was in the category of nonproduction workers, which grew by 459,000 employees; production workers decreased by 100,000. During this period, the ratio of nonproduction workers in the six industries rose from 23.8 percent of total employees to 29.3 percent, a rise of 23 percent in 10 years.

A more detailed analysis of the three-digit SIC code industries which include the 37 four-digit code industries deemed most amenable to automatic assembly shows a gain of over 200,000 workers in the 5-year period 1959–64. A large portion of this gain resulted from the shift of semiskilled workers from machining to assembly.

A comparative study of the number of operatives and assemblers in the 25 largest industrial States in 1950 and 1960 corroborated this trend and showed a 58-percent increase in the number of assemblers with only an 11-percent increase in the numbers of operatives.

The Outlook. No significant employment increases are foreseen in the coming decade among the manufacturers of automatic assembly equipment because of the projected slow growth and diffusion of the technology.

It is estimated that if machines currently available were fully used on current production volumes, 6.25 percent of the nearly 1.5 million production workers employed in the 37 industries most amenable to automatic assembly would be disemployed. The number of workers who would be affected totals 94,000.

This disemployment figure is a qualified estimate based upon a static technological and economic situation. Other industries may also be amenable to automatic assembly and the disemployment effects will not be equal in all establishments. Since the technology is in a transition stage, many technological developments can be expected in the next decade and the disemployment effect of these machines cannot be anticipated.

The disemployment estimate, it should be emphasized, does not consider assembly processes that are not fully automatic but which may have a cumulative effect upon employment that is equal to or greater than automatic assembly.

Because of the slow and restricted growth of automatic assembly, assembly work will be able to continue to absorb a considerable number of workers displaced by other aspects of automation. The decade 1975–85, however, will witness greater disemployment. This development will be significant because of the number of relatively unskilled workers, women, young people, and members of minority groups who are engaged in assembly work. Automatic assembly will tend to close off an employment absorbing sector of the economy from these workers who constitute a growing percentage of the unemployed.

Skill Requirements and Occupational Shifts

Assemblers are generally semiskilled workers engaged in routine operations. Special training is usually of short duration and is normally obtained in-plant on the job. Skilled assemblers are required in some industries, usually in final assembly.

Automatic assembly will disemploy those workers whose tasks are directly performed by the machines. Some semiskilled jobs will be created by the necessity to load, feed, operate, and monitor the automatic machines.

New occupations will be established for machine maintenance. Mechanical skill and knowledge of electronics and servomechanisms will be required. Computer technicians will eventually be needed when programable machines come into use. Inspectors, quality control men, machine and product designers will be needed at the professional level.

7. Automatic Assembly

The Technology

The term fabrication, as it is commonly used, refers both to the production of individual piece parts and to the combining of these individual piece parts to generate a useful product. The latter activity is commonly referred to as assembly.

Assembly is the process of combining individual component parts to form a useful product. If the formed product is to perform its ultimate function without further combination with other piece parts or products (e.g., an automobile), it is commonly referred to as a final assembly. If, however, the product must be combined with other components before it can perform its ultimate function (e.g., an automobile's voltage regulator), it is commonly referred to as a subassembly.

Within the last few years there has been an increasing awareness of the significant role assembly plays within the entire industrial economy. One authority has estimated that from 50 to 60 percent of the time, money, and manpower invested in the total manufacturing process is spent on assembly. The excessive absorption of labor resources by the assembly activity is due to the fact that assembly remains mostly hand work while many of the other major production processes are highly mechanized.

Automatic assembly remains in its infancy and the reasons are widely recognized and well recorded. As reported by Foster: [22]

1. Automatic assembly involves very complex mechanical handling, and the economics are often on the side of human labor.
2. Automatic assembly can best be applied to components that will go together without difficulty; otherwise the process will come to a grinding halt, to the accompaniment of very expensive noises. In turn this involves either 100 percent inspection of the components to be fed to an automatic assembler (or their inspection within the machine itself), or alternately, the component parts must be designed so that every conceivable act of mismanufacture cannot cause assembly trouble. This latter is a very unlikely achievement.
3. Unlike most machine tools, automatic assemblers are custom built to suit a particular assembly and since they are expensive, the obsolescence risk is very high if product changes are to be made.

A fourth reason, not stated above, for the relative lack of automation in the area of assembly, is that about 8 to 10 years ago there was an over-enthusiastic attempt to fully automate assembly operations by several manufacturers. The results were extremely disappointing and cast a stigma over automatic assembly that is only now disappearing.

In 1954, research was initiated at the Harvard Business School which was aimed at the analysis of the management implications of rapid technological progress in the area of production. Two studies established that special machines appeared to be good investments but many unexpected difficulties were encountered. Almost all of the problems appeared to be a consequence of newness and unfamiliarity. Many projects took longer than expected, cost more than budgeted, did not perform as efficiently as desired, and, in general, required more energy, skill, and resources than anticipated.

The initial study was conducted by James R. Bright in 1955–57, who reported that special machines had special problems:

> Regardless of who makes the equipment: The user, an automatic specialist, or an old line machining manufacturer—this equipment is harder to build than most people think. Automation is a difficult mechanical art.[23]

The second study included a comprehensive and penetrating analysis of 47 special machine projects. After a year study of 18 plants and 9 vendors of special automatic equipment it was concluded that the acquisition of special automatic equipment was a complex and difficult task and more risky than the acquisition of production facilities generally.[24]

Assembly Machines. Assembly machines can be classified as general purpose and special purpose machines. Special purpose machines can be further subdivided into proprietary machines (built to order for the assembly of a particular item) and standard machines (those that exist in some degree of completion in the manufacturer's inventory).

Special Purpose Assembly Machines. Many proprietary machines are designed by the using company and built by specialty machine companies. The machines are used for high speed

[22] D. Foster, *Modern Automation*, London, 1963.

[23] J. R. Bright, *Automation and Management*, Harvard University, Cambridge, 1958.

[24] P. Niland, *Management Problems in the Acquisition of Special Automatic Equipment*, Harvard University, Cambridge, 1961.

production in many industries where the products are small and produced in volumes running into the millions each year.

Standard special purpose assembly machines are not special purpose in the same sense that a can-making machine is. They are not built to the customer's design, but are more in the category of semiautomatic machine tools, since they can be adapted to perform a whole class of assembly operations. Retooling is more expensive, however, than for a semiautomatic machine tool, averaging 30 to 50 percent of the original machine cost. There are five or six major producers of these machines who produce them in a variety of sizes. The machines are constructed of standard, interchangeable units, making their cost much less than for specially designed machines. These machines are of two kinds, rotary indexing machines and in-line transfer machines.

Rotary indexing machines. Rotary indexing machines have a round table with the assembly machine heads mounted around the circumference. Typically their use involves a worker in the cycle, with the major component fastened into a fixture or pallet and indexed around the table from station to station where the other components are fastened to it. At the end of the cycle the worker removes the finished assembly. As many as 20 to 25 components can be assembled in one rotation of the table.

In-line transfer machines. In-line machines are also indexing machines. The pallet, or holding fixture, moves along the machine and is transferred from work head to work head. Empty pallets are returned to the loading station on a conveyor running beneath the machine table. The pallets are manually loaded and unloaded, requiring the services of two workers for the single-side model. In the double-side model, the pallets move in a rectangular path around the periphery of the machine and one worker can both load and unload. With both the in-line and rotary machines it is essential that the assembly be performed with the major component held in a fixture.

The in-line machine has some advantages over the rotary machine. New stations can always be added, either at the end or in the middle. The capacity is not fixed as it is on the rotary machine. In-line machines also allow for easier access for maintenance and tooling and it is easier to insert a worker in the line.

There are on the market a large number of standardized hoppers and selectors for attachment to these indexing assembly machines. These devices store the part, select those having the desired orientation, and forward them into a track or magazine for transfer into the assembly location.[25]

[25] K. R. Treer, *Parts Selectors*, Manufacturing Engineering Council, North Olmstead, Ohio, 1962.

General Purpose Assembly Machines. These are the machines frequently referred to as "robots," and a number of them can best be described as one-armed mechanical men. They are designed to perform a variety of transfer or simple assembly operations, but at present their manufacturers are emphasizing transfer applications. The advantage of the general purpose over the special purpose machines lies in their ability to do a number of different tasks by relatively simple reprograming.

Historically, the dexterity solutions developed by the Atomic Energy Commission for their manipulators of radioactive materials were perhaps the forerunners of today's general purpose machines. However, it took the marriage of two technologies—dexterity solutions and the positioning technology developed for servomechanism applications—to make general purpose machines a reality.

General purpose machines will probably find their best assembly applications in the production of large products because they are well suited to performing assembly operations from an external position relative to the work. By comparison, special purpose machines lend themselves better to small assemblies where the operation takes place while the work is passing through or under a work station.

Programing these machines is accomplished by manually moving the manipulator through the desired motion path. By means of push buttons, continuous recording, or other means, the manual movements are stored in memory by the controller on magnetic tape, a drum, or other storage device. Once programed these machines can continuously reproduce the original manual movements.

General purpose assembly machines are expensive, and the larger ones are being used mainly for transfer work that is particularly fatiguing or unpleasant. In these situations, the payback period is often short and workers are inclined to accept the machines readily. As an example of the short payback period possible in an installation of this type, in one application, work was performed 3 shifts a day, 7 days a week, by operators being paid $4.32 per hour. Savings from the displacement of three operators required per shift meant a payback period of 5 months on approximately a $24,000 machine.

Technical Problems of Automatic Assembly. There are four major technical problems of automatic assembly not related to the assembly machine itself. Two of these, product design for automatic assembly and component reliability, are prior to the process, and two others, component orientation and process inspection, occur in production.

Product Design for Automatic Assembly. In designing components for automatic assembly, the engineer must frequently rethink basic design principles. For example, one accepted general principle calls for having as few components as necessary to constitute the assembly. This principle must now be modified to make components sufficiently simple so that they do not snarl when handled in bulk, can be oriented with ease, and can be assembled with simple, direct motions.

Component design can greatly influence the ease with which components are handled in hoppers and automatic feeders. Devices used in automatic part-feeding hoppers rely on the tendency of the part to fall, position, or deposit itself in a given attitude. The automation engineer tries to determine for each part the attitude it is most likely to take and hold. He then inserts into the system a device to eject all parts not in this attitude. All parts in the correct attitude are automatically fed into the assembly machine.[26]

Designers are learning that simple, straight-motion, self-fasteners are preferable to threaded fasteners that require rather intricate equipment for feeding and turning. Screws, nuts, and bolts are giving way to riveting and staking, which frequently means that the assembly cannot be taken apart for repair. Permanently sealed, discardable subassemblies and self-lubricating mechanisms are becoming more popular, partly for this reason. Instead of repairing them, they are discarded as units, and new units are installed.

Component Reliability. The reliability of an automatic assembly process is a function of both component reliability and machine reliability. Of these, component reliability presents the greater problem.

With removal of the human assembler, who could detect even slight flaws in components, a thorough analysis of component reliability becomes essential. This usually results in a marked upgrading of acceptable reliability levels because even the most elaborate type of control instrumentation cannot adequately replace the senses of an assembly worker.

In automatic assembly, part tolerances must be held very tight and flaws or dirty parts, formerly considered minor problems, can take on major significance when they cause downtime on expensive automatic machines. To illustrate the problem of machine downtime resulting from unreliable components, consider this hypothetical situation. Assume a machine assembles 20 components, each component being assembled by a separate machine head in one-tenth of a minute. The production rate of the machine would theoretically be one assembly each one-tenth minute, or 4,500 per 450 minute shift. Assume also that the entire machine stops each time a machine head is jammed or prevented from operating by a faulty component. If the number of defectives averages only 1 percent for each component, and each time the machine stops for a defective component it takes 2 minutes to get it started again, then the machine will be down 80 percent of the time, and production will drop from a theoretical 4,500 per shift to only 900 per shift. To reduce machine downtime, component reliability would have to be greatly improved, the number of components assembled by the machine reduced, or the machine be made self correcting.

Component Orientation. Another major technical problem of automatic assembly is that of gaining control over, and maintaining proper orientation of the components. The difficulty involved in achieving proper component orientation has given rise to the practical idea of not losing control of a part once control has been accomplished. Two related factors define the orientation problem: 1) The number of planes of symmetry or complexity of shape of the component, and 2) the number of planes of entry, or ease of insertion of the component into the assembly.

The shape of a component greatly influences the ease with which it can be automatically handled and positioned. A sphere, whose planes of symmetry are infinite, can be most easily handled, whereas a component that can take only one position at the point of assembly is most difficult to handle.

In addition to designing components for ease of automatic handling, there is the problem of awkward shapes and parts such as springs, which tend to snarl. This can sometimes be solved by keeping control over the orientation of such components during the entire manufacturing process. One way of achieving this is to integrate machining and assembly. The problem of a snarling coil spring, for example, can be solved by putting an automatic spring-winding station in the assembly machine and have it make springs as they are used. Another solution is to have springs manufactured and placed directly into a magazine for use on the assembly machine.

There is also frequently a problem of inserting awkwardly shaped components into an assembly, since it is difficult and costly to accomplish a change of direction during the inserting motion. Complex motions involving two or more axes of movement, such as a horizontal insertion followed by a vertical thrust, require more intricate mechanisms than simple straight-line motions. The solution to this problem frequently lies in redesigning the component into more simple form.

Orientation is very difficult to maintain over components that lack rigidity or trueness of shape.

[26] P. C. Noy, "Automatic Assembly: Check-Chart for Single-Part Complexity," *Product Engineering,* Mar. 31, 1958, pp. 124–5.

Flexible parts of indeterminate attitude, such as lengths of thin wire, paper, cardboard or plastic insulation, rubber gaskets, and so forth, are difficult to control and insert automatically. Such components may require the inclusion of a manual station in an otherwise automated assembly line. Manual stations may also be required for the assembly of fragile parts or materials which may not be able to withstand the mechanical action of bulk feeding devices.

Process Inspection. Automatic assembly has both an advantage and a disadvantage in process inspection. The advantage is that it allows for economic and effective use of 100 percent inspection of measurable quality characteristics. The disadvantage is that removal of the human assembler makes it extremely difficult to inspect and control attributes of quality, such as color, surface finish, or general appearance.

With 100 percent inspection possible, the once outmoded technique of selective assembly can be used again with great benefit—components of slightly differing size can be selectively mated in assembly to produce a product held to tight tolerances without increased precision in machining.[27]

A distinct disadvantage of automatic assembly is the loss of continuous surveillance of the parts and process normally performed by assembly workers. Machines are still incapable, except at prohibitive costs, of exercising a general overview of the quality attributes of a process. Frequently this function is performed in automatic assembly by a worker who is also assigned the task of feeding large or awkward parts into the machine, or removing finished assemblies.

Two basic kinds of inspection control systems are used on assembly machines, instantaneous and memory. The instantaneous system stops the assembly machine on detection of a malfunction, while the memory system ejects bad parts or assemblies at a subsequent time without stopping the machine. A memory system does not assure continuous machine running, however, since persistent malfunction will inevitably force human intervention and usually machine shutdown. It can mean less machine downtime, though, since the machine will keep running despite sporadic malfunction.

Automatic Assembly In Operation. Certain industries, notably automotive and electronics, have accomplished varying degrees of automatic assembly on some mass production items. In the following examples, the products are mostly rather small, of stable design, and are made in very high volumes. Assembly has been performed mostly by special purpose machines.

Automatic Assembly in the Automotive Industry. The automotive industry has achieved some automatic assembly on internal mechanisms and subassemblies, but not on final lines. The automatic assembly is done by special purpose machines, many designed by the automotive companies themselves, but a fair portion of them built by specialty companies.

Engine-block assembly line. This uses an in-line machine, whose design follows closely that of a machining transfer line. It has a heavy cast bed with ways, indexing mechanisms, and locating stations. Engine blocks are indexed from station to station, located and securely held while the assembly operations are being performed.[28] This machine is illustrative of the class of in-line indexing assembly machines used in the automotive industry for major components.

Piston connecting-rod assembly machine. This is a rotary indexing machine made by a specialty company to assemble the two major parts of the piston connecting rod with two bolts and nuts. One operator on this machine does the work of a previous 20-man line. The machine turns out about 3 million rods per year on a two-shift basis and is illustrative of the class of rotary indexing machines used in the automotive industry for smaller subassemblies.

Spark plug assembly line. This makes almost the entire plug automatically and automatically packs the completed plugs into boxes. The line contains several automatic inspection and monitoring stations and is typical of the very high volume in-line machines used for small automotive parts. Including assembly workers, setup, and maintenance men, the line represents a labor cost reduction of 66 percent compared with the previous hand assembly method.

Automatic Assembly in the Electronics Industry. The invention of printed circuitry and solid state components has allowed the assembly of many electronic devices to be made virtually automatic. With automatic inserting machines, programed assembly of electronic components to printed circuit boards is economical for fairly short runs. A board of smaller size, containing about 30 components, requires about 20 minutes for hand assembly. It is assembled in about 1.5 minutes with a relatively slow type of automatic inserting machine.

Automatic Assembly in Other Industries. For many years light bulbs, radio tubes, tin cans, and some safety razors have been automatically as-

[27] R. Esken, "Automatic Assembly," *Mechanical Engineering*, May 1960, pp. 40–42.

[28] G. H. Degroat, "Automatic Assembly," *American Machinist*, Sept. 10, 1956, pp. 130–148.

sembled on proprietary machines built especially for the purpose. More recently ball bearings, roller skate wheels, ball-point pens, and parts of cameras have been assembled automatically on machines considerably more sophisticated than those used for the first group. Most recently, items involving many moving parts, such as watt-hour meters and clocks, have been automated.[29]

At one of the largest American clock makers, one clock assembly has been made almost totally automatic. The line produces about 6,000 clocks per day at a cycle time of 4 seconds per assembly station. There are 57 assembly machine heads in a line stretching for a length of about 170 feet. Fifteen workers man the line, doing maintenance, inspection, feeding, and miscellaneous work. The line assembles the entire clock.

The above examples demonstrate that automatic assembly can be achieved economically for standardized products that are not too large, are of stable design, and are produced in very large volumes. Most assembled products, however, do not fit this description. Either they are not sufficiently standardized or the volumes produced are not large enough. Techniques of automatic assembly to meet the general needs of fabricating companies have yet to be developed.

Technological Trends

The technology of automatic assembly derives, in part, from automatic machining. It is sometimes difficult to distinguish where machining leaves off and assembly begins in automatic installations, for many machining operations have either replaced or been combined with assembly operations. Die-casting as a fastening operation is an example.

The special purpose assembly machines are further advanced than general purpose machines and will retain this lead for some time. This is natural since special purpose machines are patterned after automated machine tools, whereas general purpose machines are almost an entirely new concept. Furthermore, since work being done manually on assembly lines lends itself quicker to automatic assembly for which special purpose machines are especially adept, special emphasis will be placed on the development of these machines.

In attempting to build a general purpose machine capable of handling many applications, more difficulties must be overcome than for a single purpose machine. General purpose machines will find their greatest early usefulness in the assembly of larger products and in automating certain batch type work. They should also be useful to load and unload special purpose assembly machines. Of these, unloading will be the easier application, since it is almost always done with the object already oriented and firmly located.

It is in the area of general purpose or computer controlled machinery that automatic assembly will make its greatest strides. This does not imply a future abundance of the anthropomorphic types of "robots" discussed earlier. Machines are visualized as being perhaps similar in structure to the multistation in-line transfer or rotary machines discussed earlier, with an additional facility providing for the automatic assembly of multiple products through computer control of the stations on the machine.

Economic Considerations

Factors Influencing Economic Feasibility. The roots of automatic assembly costs often lie deep in the manufacturing process Comparing the automation of a machining operation and an assembly operation, for the machining operation, cost analysis usually requires only a comparison of rather obvious direct and indirect costs incurred to produce a single part on an automatic or nonautomatic machine. In automatic assembly, however, the costs of assembling many parts must be considered. The cost of assembly becomes a function of the reliability of the assembly machine itself, as well as of the reliability of all the previously performed operations on the component parts. The costs of automatic assembly, therefore, would include such costs as those incurred to provide greater tool control and more frequent tool changes in machining operations. A correct cost analysis would assign to the automatic assembly operation all costs of providing better component quality and reliability beyond that normally required for the proper functioning of the finished product.

Volume of production is perhaps the most important factor determining the economic feasibility of automatically assembling a product. One machine tool representative says a minimum of 500,000 units annually is required for automatic assembly, depending upon assembly design and the difficulty of performing manual operations.[30] Another representative of the same tool company says that in order to utilize equipment fully, production requirements should be 600 or more units per hour, due to the short machine cycles of 2 to 6 seconds.[31]

Information on volume alone, however, is not sufficient for a good cost analysis, as labor cost and time are also important factors. High volume and high labor content normally imply a quick amortization of automatic assembly equipment. High volume with low labor content should signal a

[29] C. J. Vlahos, "Assembly Automation Runs on Toy Train Principles," *Mill and Factory,* January 1961, pp. 86–89.

[30] A. R. Wiese, "Why You Should Consider Automated Assembly," *Machinery,* March 1964, p. 93.

[31] C. C. Holloway, "The Assembly Machine Today," *Assembly Engineering,* April 1964, p. 30.

closer analysis of such factors as design stability, quality and reliability of the assembly, flexibility of scheduling, and space saving, inasmuch as this type of production is not as amenable to automatic assembly. Low volume with high labor content makes automatic assembly profitable if the design remains stable over a period of time sufficient to amortize the investment.

Model design variations and frequency of assembly must also be considered. In order to display the frequency of assembly of all models, a frequency distribution chart can be made. Following determination of frequency of assembly, design variations among models must be considered. A study can then be made of the additional expenses of more flexible machinery to handle more than one model. This entire analysis is analogous to determining whether to build various product models on several single model manual assembly lines or on a fewer number of mixed-model lines.

Stability of product design is still important, despite the increasing standardization of assembly machine elements, because a total assembly system requires considerable tooling and engineering expense. Many opportunities, however, for worthwhile automatic assembly applications are lost, because no one has the courage to freeze product design for a period of time, even though the same designs continue unchanged for years.

Product complexity may dictate the method of assembly. Complex assemblies, requiring compound motions of assembly machines, often mean that semiautomatic assembly or manual operations with mechanical assists should be used, rather than fully automatic equipment.[32]

A receptive atmosphere, including all levels of management and engineering and production personnel through the plant level, is an important intangible for a successful automatic assembly venture.

It appears that operations performed on progressive assembly lines are easier and less costly to automate than those performed by the single station bench or batch method. The relative ease and lower cost derive from the easier analysis by the machine designer of the more simplified tasks performed on a line, the better methods and better designed parts usually existing on lines, and the better orientation of product and components on assembly lines.

Specific applications for automatic assembly are considered by one company wherever several operators perform the same operation, the job requires difficult or continuous product handling, a production bottleneck exists, a high number of rejects occur due to the human factor, or large in-process inventories are involved.[33] The presence of any of these conditions shows an area for study, but it does not alone show justification for automatic assembly.

One machine tool representative says that prospective assemblies should generally contain at least four components. Otherwise, the small number of stations relative to basic machine costs makes automatic assembly uneconomical.[34]

In considering any application for automatic assembly, either the best method of hand or manual assembly should be in use or improvements should be considered for the cost analysis.

Costs, Savings, and Cost Analysis Methods. If an operation is technically a good prospect for automatic assembly, the evaluation of many cost and savings factors can proceed. Table 24 lists important costs experienced with automatic assembly and table 25 lists the savings. These factors should be included in comparative cost evaluation.

Machine and Production Efficiency. Determination of the production rate of a machine before it

TABLE 24. COST FACTORS OF AUTOMATIC ASSEMBLY

Cost factors	Remarks
Initial	
Assembly machine	Approximately 25 to 35 percent of total cost is for basic assembly machine, 40 to 50 percent for engineering, development, and system building, and 25 percent for debugging. Debugging can range from 10 to 50 percent.[1]
Auxiliary equipment	Hydraulic pressing stations, welding stations, intricate gauging and inspection stations, etc.
Engineering	Automation engineering staff.
Installation	
Liaison with machine builder.	Correspondence, telephone, trips by company staff.
Parts used for debugging.	
Product and parts design	May be required economically to automate, primarily to solve component orientation or insertion problems, and to improve component reliability.
Tooling and retooling	Includes initial machine tooling, which cost 1.5 to 2 times as much as for manual assembly, and job change retooling, which can cost as much as 30 to 50 percent of initial tooling.
Training	Personnel to operate, maintain equipment. Can be minimized by training during debugging stage of machine development.
Recurring	
Closer parts tolerances	Precise dimensions must be maintained throughout manufacturing; tool room costs rise because of more frequent tool checking and maintenance.
Component cleaning	To assure automatic feeding.
Operating	Charges for expendable tools, electric, water, fluid power services, and maintenance.
Wages	Increase due to high skill required of workers remaining after machine installation.
Intangible	
Flexibility	Difficult (perhaps impossible) to build a differently designed product with the same machine, or to change hourly production rate of the machine.

[1] In smaller systems, the basic machine will be the predominant cost element, while in larger systems it will be the control system.

[32] G. H. Kendall, Sr., "How to Plan for Automatic Assembly," *The Tool Engineer*, February 1958, p. 97.

[33] R. H. Eshelman, "Automatic Assembly—Victory for Production," *The Tool Engineer*, September 1956, p. 116.

[34] A. R. Wiese, *op. cit.*

TABLE 25. SAVINGS FACTORS OF AUTOMATIC ASSEMBLY

Savings factors	Remarks
Closer product tolerances without increased precision in machining.	Due to possibility of 100 percent inspection and selective assembly with automatic equipment.
Better working conditions.	Fewer accident, health, and fatigue costs.
Greater precision	Resulting in fewer cases of customer complaints, field service calls, and product returns.
Inventory (in-process and completed).	Inventories held are usually at lower level of economic value. They are in the form of parts, rather than in-process or completed assemblies, which contain the added values of labor and more material.[1]
Labor	Direct and indirect, including inspectors and administrative and service personnel.
Materials	
Scrap and rework	
Space	Occupancy of both equipment and direct and indirect labor.

[1] Inventories can often be kept lower, at least to increased output requirements, because automatic equipment is more responsive than manual assembly. It is easier to run a machine extra shifts than to hire extra operators, and no premiums or side benefits are required.

is built is often a problem and makes evaluation and justification of automatic assembly very difficult. The probability aspects of both machine and component reliability are the reasons for difficulty in answering the question, and machine builders and the literature discuss this problem in terms of machine efficiency.

Machine efficiency is defined as the ratio of assemblies actually produced per unit time versus the theoretical production per unit time. Efficiency depends largely upon the nature and number of operations and the type of machine tooling used. Builders often guarantee machine efficiency at 80 percent but these guarantees can range down to 70 percent. In practice, machine efficiency can reach as high as 95 percent.[35]

It should be noted, however, that there is a difference between machine efficiency and production efficiency. The latter is defined as the ratio of assemblies actually produced per unit time versus the number of machine cycles (perhaps parts input) per unit time. Production efficiency depends mainly upon the type of inspection system used on an assembly machine, instantaneous stop or memory, which ejects bad parts or assemblies at a subsequent time without stopping the machine.

To illustrate the difference between machine and production efficiency, assume a machine with an instantaneous inspection system designed to deliver 600 units per hour. Because of component and machine reliability factors, however, the machine's theoretical production is computed to be 480 units per hour. The machine is observed to be producing only 400 units per hour, due mainly to shutdowns controlled by the instantaneous inspection system. In this example, the machine efficiency is 400/480 or 83 percent, but the production efficiency is only 400/600 or 67 percent, a 16 percent difference. To improve efficiency, component and machine reliability might be improved, the number of components assembled by the machine reduced, or the machine could be controlled by a memory inspection system.

As a general guide, it has been observed that economically sound automation for smaller assemblies costs from $5,000 to $7,000 per single station on a special purpose assembly machine. With the overhead typical of most companies and the somewhat higher maintenance costs of automatic equipment, the payback period is about 1 to 2 years on a single shift operating basis. Similar figures apply to the smaller general purpose machines. More costly special purpose equipment and the larger general purpose machines can usually only be justified on a two- or three-shift basis. It is expected that the cost figures cited will go down as development costs are reduced through increased standardization of assembly equipment, and as users develop experience and skill in designing their products for automation.

[35] Holloway, *op. cit.*, p. 31.

Skill Requirements and Occupational Shifts

Assemblers are generally semiskilled workers engaged in routine operations. Special training is usually of short duration and is normally obtained in-plant on the job. Floor assemblers assemble large, heavy machinery or equipment on the floor of a manufacturing establishment as on an automobile or aircraft production line. Bench assemblers are engaged in the assembly of small parts or subassemblies at a bench or work station.

In 1963, approximately 600,000 semiskilled assemblers worked in manufacturing plants, the majority in metalworking. More than 46 percent of these assemblers were women.

Skilled assemblers are required in some industries such as watch manufacture, precision instrument, and specialized and complex machinery. They are generally engaged in final assembly.

Automatic assembly will disemploy those workers whose tasks are directly performed by the machines. Some semiskilled jobs, generally requiring little training, will be created by the necessity to load, feed, operate, and monitor the automatic machines.

New occupations will be established for the maintenance of the machines. The essential skill required will be mechanical. As the technology develops, however, skills in electronics and servomechanisms will be required. Computer technicians will eventually be needed when general purpose programable automatic assembly machines come increasingly into operation.

The demand for greater component reliability imposed by automatic assembly methods could require more inspection, test, and quality control personnel. In the engineering area, machine designers will be required to develop the automatic assembly machines and product designers will be required to redesign products amenable to automatic assembly. Production specialists will be needed to improve the flow of material through automated assembly and to schedule the man-machine system for optimum effectiveness.

The latter categories of personnel are not necessarily new. They are part of the trend toward greater rationalization of the manufacturing process by design for automation and by optimization techniques. A growth in the professional categories of industrial specialists is thus indicated.

8. Growth and Diffusion

Automatic Assembly, 1950–64

Since the first progressive assembly line was started at the Ford Highland Park plant in 1913 only minor improvements have been made in assembly technology. The division of manual labor, a prerequisite to the development of automatic manufacture, has long since been carried to its ultimate economy. But the next step to automatic assembly is proving extremely difficult to make. Assembly remains essentially manual work. After half a century of use the assembly line system appears to be technically static, holding a large sector of industry in the arrested state of highly divided manual labor.

While assembly remains mostly handwork, machining and forming operations are being extensively automated. The development of transfer equipment, automatic controls, and programed machine tools has sped the progress of automation in machining and forming. The relative cost factors have been such that the substitution of automation for labor is occurring rapidly in machining work.

Automation is thus progressing unevenly in the fabricating industries, moving at a rapid pace in machining departments, and slowing to a crawl in assembly departments. In walking through a production machining department one is struck by the scarcity of operators and the number of machines that seem to be running themselves. The reaction to an assembly department is quite the opposite. Here one sees workers crowded elbow-to-elbow down the line. The workers and the product dominate the scene and machinery recedes.

Automatic assembly, in the sense defined above, emerged as a specialized technology in the early 1950's. At that time several manufacturers began to market special-purpose machines that were designed to assemble particular products automatically. The manufacturers were, in several cases, originally specialty machine tool companies that developed machines on a custom design basis. The automatic assembly feature was an extension of the conveyorized, indexing type of machine and the metal cutting machine tool.

Because of the many problems associated with automatic assembly, the experience of early users was not completely satisfactory. A succession of technical problems continued to arise and costs mounted as product changes and product demand prevented an orderly and efficient utilization of the special purpose machinery. This held true especially for the machines that were designed to be reasonably flexible but were found to be relatively inflexible and unresponsive to design modifications.

The decade of the 1950's was important, however, because the problems of automatic assembly came to be better understood both in a technological and an economic sense. Both the limits and potentials of automatic assembly machines were perceived and the manufacturers and users adopted more realistic approaches to assembly.

During the past 5 years, slow progress has continued in the development of special purpose automatic assembly machines. Several user industries, especially electronics and computers, have standardized some basic components to facilitate automatic assembly. Assembly processes that utilize human operators for operations that are prohibitively costly to automate and use machines for simple mechanical operations are becoming more widespread. Advances continue in the pioneering automotive industry.

An industry source in the automatic assembly field estimates the market potential for automatic assembly machines to be about $250 million. Since the cost of the average automatic assembly system produced by this firm is approximately $100,000, a market for about 2,500 machines is implied. Because this manufacturer makes a line of assembly systems that are more completely automated than several other systems on the market, however, the cost figure cited may be higher than the industry average. A more representative estimate of the cost of the average system would be somewhat lower and the number of potential units that could be marketed would be higher when based on the same total market figure.

Estimates provided by several industry sources are rather consistent in identifying the major industrial users of automatic assembly equipment. It is believed that the automotive industry accounts for between 50 and 70 percent of all automatic assembly installations. From 5 to 15 percent is accounted for by the consumer appliance industry, and the remainder by all other industries. Reasons given for the low degree of automation in the consumer appliance industry emphasized the bad experience the industry had had with early automation and the lower production volumes rela-

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tive to the automotive industry. Stronger interest in automatic assembly on the part of the consumer appliance industries is indicated at present.

Within the industries employing automatic equipment, industry sources are again rather consistent. It is believed that from 80 to more than 90 percent of automatic assembly is in subassemblies with less than 10 to 20 percent in the final assembly of products. The small degree of automatic assembly in the final assembly of products is caused by the relatively large size of final products, compared to subassemblies, and the frequent style changes of final products. Both of these factors argue against the economic feasibility of automatic assembly. It has been indicated that more small products than large products are automatically assembled in the final stage.

Diffusion Constraints

While increasing product demand and rising labor costs will continue to generate pressure to automate assembly, many factors will act to counterbalance this pressure. These factors will be called diffusion constraints, for they will tend to restrain the growth in number of automatic assembly machines and impede expansion into all areas of the fabricating industries. These constraints will impose limiting conditions on the disemployment effects of automatic assembly.

The diffusion constraints are discussed below in relation to 1) the manufacturers of automatic assembly equipment, 2) the user community, and 3) the worker.

1. *Manufacturers of automatic assembly equipment.* The number and size of automatic assembly machine manufacturers is the first and perhaps major limiting factor to substantial growth in the number of automatic assembly installations. There are only about 10 to 12 companies who produce relatively complete assembly systems. The largest company employs about 150 people in the automatic assembly equipment area. Other companies usually employ 100 or fewer workers in the assembly equipment area. Automatic assembly equipment manufacturing is in some cases carried out by subsidiaries or other subdivisions or departments of a machine tool company.

Because of the small size of assembly equipment builders, the funds for new product or idea development are limited. Thus, the equipment produced by them today is an improvement over 10 years ago, but it shows no new technology or combination of technologies as numerically controlled machine tools do. These manufacturers are geared only for small volume production and, by the nature of the product, custom designed equipment. This equipment does use increasingly more standardized parts, however.

There are a large number of assembly machines designed and built by user companies or under contract from user companies by specialty machine shops. The extent of this activity is indeterminate, but it is estimated that it could equal and exceed the number of machines built by the assembly equipment manufacturers.

Serving all assembly machine builders, either manufacturers or users building their own equipment, are about 100 or more usually small companies producing specialty devices for automatic assembly. These include devices such as parts hoppers, feeders, or selectors, gaging or inspecting devices, and so forth. The companies may often employ fewer than 20 workers. This factor also limits substantial growth in the number of automatic assembly installations because source of supply is so scattered.

2. *The user community.* The manufacturing community, the potential user of automatic assembly machines, is a highly heterogeneous collection of manufacturing establishments. The 6 fabricating industry groups include 147 industries in the 4-digit SIC code classification. These 147 industries represented more than 87,000 manufacturing plants varying in size from several workers to many thousands (1958 figures). Nearly 70 percent of the plants employed less than 20 workers but the remaining 30 percent accounted for 94 percent of the total employment and the bulk of the capital expenditures.

Industries most amenable to automatic assembly include those whose volume of production is sufficient to make it economically justifiable. These include the automotive, consumer appliance, and other industries or sectors of industries (see table 26). Within these industries, subassembly operations are far more frequently automated than final assembly operations. Automatic assembly of final products is severely limited by the size of many of the products and/or by frequent styling changes. These changes are often expensive or may be impossible to accommodate on machines built to other products' specifications. Though final product styles change, however, the subassemblies, or "black boxes," as the automobile industry sometimes refers to them, frequently remain the same. Thus automatic assembly is practical. In general, products assembled on automatic machines are rather small, of stable design, and made in very high volumes.

With the above characteristics serving to determine the amenability of an industry to automatic assembly, 37 industries are estimated to fall within this category. The 37 industries are listed in table 26 together with the total number of establishments and those with 20 or more employees, total employment and number of production workers, value of shipments, and capital expenditures.

TABLE 26. GENERAL STATISTICS, 1963, FABRICATING INDUSTRIES AMENABLE TO AUTOMATIC ASSEMBLY

Code	Industry	Establishments		Employees (in thousands)		Value of shipments (in thousands)	Capital expenditures (in thousands)
		Total	With 20 or more employees	Total	Production workers		
3519	Internal combustion engines	139	80	55,529	41,609	$1,458,189	$33,184
3562	Ball and roller bearings	125	93	52,316	42,052	1,000,962	39,235
3564	Blowers and fans	237	98	15,407	10,902	318,081	7,023
3571	Computing and related machines	248	139	99,306	59,784	2,044,796	92,754
3572	Typewriters	21	16	18,074	13,982	315,894	9,596
3576	Scales and balances	85	35	5,477	3,724	98,491	1,146
3579	Office machines, n.e.c.[1]	162	76	17,025	11,655	354,640	16,280
3611	Electric measuring equipment	557	207	44,881	30,270	745,363	19,211
3621	Motors and generators	380	241	94,075	68,583	1,704,995	37,698
3622	Industrial controls	346	108	33,485	22,888	655,355	25,631
3631	Household cooking equipment	82	52	19,078	15,027	472,114	8,162
3632	Household refrigerators	34	25	43,065	35,216	1,304,525	21,764
3633	Household laundry equipment	40	29	18,638	15,006	763,311	9,305
3634	Electric houseware and fans	311	135	38,832	30,820	835,435	17,060
3635	Household vacuum cleaners	33	13	5,675	4,231	175,314	5,737
3636	Sewing machines	86	17	7,646	5,844	117,199	2,567
3639	Household appliances, n.e.c.[1]						
3641	Electric lamps	83	50	23,851	20,850	579,809	17,146
3642	Lighting fixtures	1,235	479	54,295	42,201	1,168,843	22,877
3643	Current carrying devices	448	180	35,762	27,464	619,575	14,197
3644	Noncurrent carrying devices	182	103	20,290	14,753	478,912	7,907
3651	Radio and TV receiving sets	346	177	81,830	67,003	2,287,605	30,533
3661	Telephone; telegraph apparatus	89	55	89,241	63,809	1,704,344	55,119
3671	Electron tubes, receiving	42	22	25,850	20,357	314,246	5,403
3672	Cathode ray picture tubes	150	28	10,914	7,945	263,977	16,135
3674	Semiconductors	103	83	55,995	37,941	680,419	51,968
3691	Storage batteries	252	120	17,524	13,873	515,005	11,958
3692	Primary batteries	46	30	8,466	6,777	195,205	4,131
3694	Engine electrical equipment	184	100	41,432	33,170	915,827	15,541
3717	Motor vehicles and parts	1,950	903	649,401	535,381	36,148,831	641,802
3751	Motorcycles, bicycles and parts	85	30	9,462	7,782	189,029	3,071
3821	Mechanical and measuring devices	666	259	63,208	41,088	1,147,543	29,805
3822	Automatic temperature controls	103	54	31,579	22,178	527,498	10,646
3861	Photographic equipment	532	187	65,026	39,303	1,837,162	78,659
3871	Watches and clocks	167	76	26,610	20,713	500,852	8,529
3941	Games and toys	786	342	49,360	41,860	752,861	24,746
3951	Pens and mechanical pencils	139	67	11,562	9,062	185,464	4,066
	Total	10,474	4,709	1,940,167	1,485,103	63,377,671	1,400,592

[1] Not elsewhere classified.

SOURCE: U.S. Department of Commerce, Bureau of the Census. *1963 Census of Manufactures.*

Nearly 45 percent of the 10,474 establishments in these industries have 20 or more employees. Total employment was 1.94 million, of whom 76.5 percent were production workers. The total value of shipments of these industries in 1963 was $63.4 billion. The total capital investment (including buildings, machinery, and equipment) came to $1.4 billion.

The automobile industry (SIC code 3717), it should be noted, comprised 36 percent of the production workers, 46 percent of the capital investment, and 57 percent of the value of shipments.

The 37 selected industries listed in table 26 include many subgroups of industries, and the product line of the subgroups may be highly varied. The diffusion of automatic assembly within the subgroups of industries will be further constrained by the volume of production and in many cases by the number of workers employed in the individual establishments within these industries.

The size of establishment according to the number of workers employed in several of the 37 industries is shown in table 27.

Based largely on observation and our knowledge of automatic assembly installations in a variety of industries, it is believed that the majority of automation ventures take place, and will continue to for some time, in establishments employing 500 or more workers. This conclusion is also predicated on the volume requirements which must be present for automatic assembly, and the correlation in many industries between number of employees and production volumes.

Since many of the smaller establishments produce specialty products often in volumes below that required for automatic assembly, a large impact on the small plant from assembly automation, particularly in the 1965–75 period under consideration, is not foreseen. Harmful competitive effects on the smaller establishments for failure to automate are not anticipated because the specialty company's competition will often produce goods which are also made in insufficient quantity to be automated.

Although in many industries there is a correlation between volume of production and number of workers, the volume can be dispersed over a large product line so that no single product will be mass produced. A manufacturer of gages, for example, produces millions of gages per year. Each gage is relatively simple in construction and is similar to other gages. The more than 33,000 different

TABLE 27. MANUFACTURING ESTABLISHMENTS BY EMPLOYMENT SIZE, SELECTED FABRICATING INDUSTRIES AMENABLE TO AUTOMATIC ASSEMBLY, 1958

Code	Industry	All establishments	Number establishments with stated average of employees									
			1–4	5–9	10–19	20–49	50–99	100–249	250–499	500–999	1,000–2,499	2,500 and over
3519	Internal combustion engines:											
	Number establishments	112	18	12	7	21	4	14	8	11	12	5
	Number employees	50,225	38	79	105	608	276	2,469	2,820	7,757	18,700	17,373
	Value of shipments ($1,000)	1,055,699	792	1,474	952	9,898	7,548	51,743	40,486	171,348	357,170	414,288
	Capital expenditures ($1,000)	40,699	([1])	([1])	([1])	([1])	([1])	504	1,478	1,570	8,451	28,360
3571	Computing and related machines:											
	Number establishments	136	35	17	13	12	11	7	15	10	9	7
	Number employees	80,864	71	106	187	405	731	1,153	5,491	7,527	14,389	50,804
	Value of shipments ($1,000)	1,104,194	1,052	1,259	2,244	6,238	8,373	21,477	72,616	76,885	208,056	705,994
	Capital expenditures ($1,000)	61,494	([1])	([1])	([1])	([1])	([1])	([1])	4,407	5,122	13,935	37,024
3631	Household cooking equipment:											
	Number establishments	69	7	4	3	9	10	10	13	10	3	----------
	Number employees	18,152	85	([3])	([3])	270	701	1,452	4,506	11,138	([3])	----------
	Value of shipments ($1,000)	364,852	1,955	([3])	([3])	4,727	12,045	27,329	79,379	239,417	([3])	----------
	Capital expenditures ($1,000)	4,002	([1])	([3])	([3])	([1])	([1])	586	1,009	2,172	([3])	----------
3632	Household refrigerators:											
	Number establishments	26	----------	----------	----------	2	([3])	5	5	2	7	4
	Number employees	41,493	----------	----------	----------	153	([3])	914	3,180	([3])	11,671	25,575
	Value of shipments ($1,000)	1,002,302	----------	----------	----------	2,464	([3])	15,059	74,736	([3])	304,001	606,042
	Capital expenditures ($1,000)	9,870	----------	----------	----------	([1])	([3])	([1])	([1])	([3])	4,272	5,018
3651	Radio and TV receiving sets:											
	Number establishments	234	38	27	25	27	25	34	21	17	17	3
	Number employees	66,505	81	188	366	894	1,808	5,391	7,379	12,283	25,709	12,406
	Value of shipments ($1,000)	1,548,006	1,293	3,370	6,566	15,723	30,425	82,989	144,861	291,933	678,908	291,948
	Capital expenditures ($1,000)	11,308	([1])	([1])	([1])	([1])	([1])	903	1,243	2,253	3,886	1,701
3661	Telephone and telegraph apparatus:											
	Number establishments	95	26	10	4	6	7	10	10	6	8	8
	Number employees	85,544	51	69	47	200	464	1,871	3,635	4,371	74,836	([3])
	Value of shipments ($1,000)	740,855	536	564	252	2,011	4,713	12,584	32,421	40,415	647,359	([3])
	Capital expenditures ($1,000)	103,517	([3])	([3])	([3])	([3])	([3])	([3])	([3])	([3])	([3])	([3])
3717	Motor vehicles and parts:											
	Number establishments	1,551	411	191	205	212	121	113	79	62	97	60
	Number employees	541,510	884	1,288	2,880	6,723	8,483	18,480	27,715	44,856	163,725	266,476
	Value of shipments ($1,000)	[2] 6,473,927	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
	Capital expenditures ($1,000)	314,646	1,263	947	1,373	2,975	2,537	7,351	13,811	18,458	140,407	125,522
3861	Photographic equipment:											
	Number establishments	480	178	68	75	68	31	30	15	7	4	4
	Number employees	460,262	352	455	1,037	2,186	2,090	4,637	5,044	4,906	39,555	([3])
	Value of shipments ($1,000)	1,204,905	6,339	7,941	20,471	40,617	49,973	88,156	100,313	96,437	794,658	([3])
	Capital expenditures ($1,000)	46,770	([1])	([1])	([1])	718	([1])	1,698	2,439	1,479	38,887	([3])
3871	Watches and clocks:											
	Number establishments	168	66	16	21	20	17	7	9	5	6	1
	Number employees	23,505	130	101	310	632	1,217	1,214	3,527	4,309	12,065	([3])
	Value of shipments ($1,000)	334,928	2,635	4,200	5,512	12,619	23,043	13,731	61,443	52,356	159,389	([3])
	Capital expenditures ($1,000)	4,607	([1])	([1])	650	([1])	([1])	([1])	881	([1])	2,199	([3])

[1] Value less than $500,000.
[2] Value added instead of shipment.
[3] Combined with other size class.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *1958 Census of Manufactures.*

types of gages the company offers, however, preclude automatic assembly by a special purpose machine because of differences in size, shape, etc.

3. *The worker.* The diffusion rate of a technology is a function of other factors in addition to engineering, production, and economic factors. The technology is embedded in a social system in which economic values must often compete with other values and the allocation of resources and manpower has many contending claimants.

The factory, too, is a social system as well as a production system. The attitudes and responses of the workers as expressed individually and collectively through unions will serve as constraints on the diffusion of automatic assembly as well as of NC. Worker satisfaction, occupational status, the problems involved in the changing requirements for skills, and seniority are real and vital problems to millions of workers. The unions, especially, are closely attuned to the problems arising from the intersection of the socioeconomic factors and the social factors in automation.

Automatic Assembly, 1965–75

The Transition Stage of Diffusion. In terms of the diffusion model described in part 1, the automatic assembly technology has completed the stage of pretechnology and is now in the transition stage. More models of automatic assembly machines are being produced in a varying price range. An increasing number of applications are being found. A growing awareness of the potentials of these machines coupled with a realistic appraisal of their limitations is percolating through the manufacturing industries.

The transition period will probably be a lengthy one in contrast to the short periods experienced by the computer and numerical control technologies. It is not clear at this time whether automatic assembly will complete its transition phase during the next decade. Manufacturers of automatic assembly equipment are optimistic over sales in the next few years. However, the small volume of machines and the many technical problems arising from specialized assembly operations indicate a slow diffusion process extending over many years.

The takeoff stage for automatic assembly may have to await solution of the flexibility problem; i.e., the development of a programable assembly machine. Because there are thousands of factories with a multitude of diverse products in many models, the development of special purpose machines will continue to be a slow and costly procedure. The cost of the special purpose machine in relation to model design longevity will also inhibit its use. A programable machine that can be mechanically altered in a simple manner and that can be instructed to proceed through a sequence of operations by dial, plugboard, punched card, or tape is the essential requirement for the takeoff stage. This type of machine can be compared to today's numerically controlled machining center.

One assembly machine builder indicated that they are interested in looking further into programable tooling, but that they are not doing anything in this area at the present time. Another builder stated that they were working on programable tooling but the stage this development is in is not known. It is significant that one of the major computer manufacturers has recently been licensed to manufacture and market the assembly systems of one of the major assembly machine builders. With the capabilities and resources this computer manufacturer can bring to bear in product development, manufacturing, and marketing, more rapid strides in the future to a more flexible automatic assembly machine can be expected.

Diffusion rate. With the likelihood that the type of automatic assembly equipment in use today will continue to be the dominant factor in the field through at least most of the next decade, a great change from the industries presently applying the equipment is not visualized. However, assembly machine builders, as already indicated, do see greater interest now on the part of the consumer appliance industry. The automotive industry will still be the dominant factor.

The assembly machine builders are expecting an increase in their rate of growth over the next few years with estimated average growth rates as given by a few companies ranging from about 10 to 12 percent. The growth rate definitely follows evolutionary rather than revolutionary trends. A restraint on growth rate of the companies is due in part to limitations of their own capabilities, training of larger engineering staffs, and so forth. The growth is expected as a result of improved knowledge of applications by users, lower machine costs due to increased size of the builder companies, component standardization, and replacement market for existing automatic assembly equipment.

A feeling was expressed by one builder that machine tool companies will enter the automatic equipment field more forcefully in the years ahead.

9. Impact of Automatic Assembly on Employment

Employment Review, 1950–64

The employment review in section 5 (part 1) is applicable to automatic assembly as well as to NC. Employment and unemployment rates for operatives during the period 1947–64 are shown in table 18. Operatives are semiskilled workers and include the majority of assemblers.

A more detailed employment review which lists many of the four-digit SIC code industries estimated to be amenable to automatic assembly appears in table 28. Employment figures for the three-digit SIC industry group are displayed when more detailed figures were not available.

A comparison of the 1959 and 1963 figures on employed production workers (1958 was a recession year) shows an increase occurred in nine four-digit industries and a decrease occurred in seven four-digit industries. Five of the increases were less than 3,000 workers, and four 3,000 or more workers. Computing machine employment increased by 5,000, electric measuring equipment increased by 5,500, lighting fixtures by 3,000, and current and noncurrent carrying devices by 6,600. Employment in receiving tubes decreased by 9,800 workers and in engine electrical equipment by 6,600 workers.

The largest gains in three-digit industries were in motor vehicles and equipment (SIC 371) with 39,200 workers, and toys and sporting goods (SIC 394) with a gain of 3,200 workers.

A net gain of 201,400 workers occurred between 1959 and 1963 in the 18 three-digit industries which include the 37 industries deemed most amenable to automatic assembly.

A large portion of this gain resulted from the shift occurring in the ranks of semiskilled workers from machining to assembly. As the component machining departments are automated, machine operatives are laid off or transferred to the assembly line. To document this shift a comparison was made of 1950 and 1960 Census employment data for the 25 largest industrial States to show the change in employment of assemblers and operatives in the fabricating industries over this period. For each State the ratio of assemblers to operatives was found for 1950 and 1960 and the change in this ratio determined. Table 29 shows that the number of assemblers employed in these industries in those

TABLE 28. PRODUCTION WORKERS EMPLOYED IN INDUSTRIES AMENABLE TO AUTOMATIC ASSEMBLY, 1958–63

Code		Industry	Production workers (thousands)					
			1958	1959	1960	1961	1962	1963
	3519	Internal combustion engines	33.8	39.1	35.8	30.7	36.2	36.5
356		General industrial machinery	139.1	155.2	157.2	146.6	154.8	156.8
	3562	Ball and roller bearings	34.4	42.8	41.7	37.8	40.7	40.9
357		Office machines	87.8	92.7	95.9	96.3	98.7	95.1
	3571	Computing and related machines	57.1	60.2	63.5	64.7	68.0	65.2
	3611	Electric measuring instruments	27.4	32.1	34.3	35.0	38.4	37.6
	3621	Motors and generators	61.0	70.9	70.0	66.6	68.9	68.1
	3622	Industrial controls	23.5	29.0	30.1	30.0	32.3	31.9
363		Household appliances	112.6	121.8	119.4	112.9	114.8	118.7
	3632	Household refrigerators	34.6	39.2	38.4	36.0	36.5	36.9
	3633	Household laundry equipment	19.9	20.9	19.2	18.3	18.8	19.1
	3634	Electric housewares and fans	23.0	25.3	26.0	23.5	25.6	27.1
	3641	Electric lamps	22.7	24.8	25.5	23.6	24.9	25.9
	3642	Lighting fixtures	33.4	36.9	37.2	36.2	38.1	39.9
	3643, 4	Current and noncurrent carrying devices	37.4	43.6	44.3	45.4	48.5	50.2
365		Radio and TV receiving equipment	77.1	84.7	79.2	75.4	82.5	84.0
	3661	Telephone; telegraph apparatus	64.4	68.1	74.0	72.4	76.5	69.9
367		Electronic components	133.9	160.9	170.0	176.7	198.2	192.1
	3671	Electron tubes, receiving type	51.6	55.6	52.3	48.0	49.8	45.8
369		Electrical products, n.e.c.[1]	72.7	81.7	81.8	74.7	78.9	75.0
	3694	Engine electrical equipment	42.5	49.1	50.1	43.8	46.0	42.5
371		Motor vehicles and equipment	452.5	537.5	563.3	479.1	534.0	576.7
	3822	Automatic temperature controls	18.8	22.4	23.5	23.4	24.3	24.7
386		Photographic equipment	41.2	41.3	41.4	40.2	41.1	41.5
387		Watches, clocks, and watchcases	20.9	23.5	22.1	20.9	22.7	23.8
394		Toys and sporting goods	78.6	82.4	84.1	81.6	85.2	85.6
395		Pens, pencils, and office supplies	21.7	22.8	22.6	22.1	23.1	23.7

[1] Not elsewhere classified.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Earning Statistics for the United States, 1909–64*, Bull. No. 1312-2, December 1964.

States increased from 292,853 in 1950 to 463,355 in 1960. This is an increase of 170,502 assemblers, or 58.2 percent over the 1950 figure. In the same period the number of operatives increased from 855,564 to 952,716, or only 11.4 percent over the 1950 total. The 16 largest States all show an increase in the ratio of assemblers to operatives in the decade.

The Michigan data are particularly interesting because they show a decline in this period of almost 35,000 operatives and only about 600 assemblers. This is a dramatic illustration of the differential displacement effects of automation in machining and assembly. Detroit automation is mostly machine automation which disemploys semiskilled machine operatives. Michigan, a machine-intensive State, exports much of its machined work in the form of automobile components to be assembled in other States, and the effect of automation is indicated by a net decline in employment. Other States, such as California, for example, where not only automobiles machined elsewhere are assembled and where other assembly-intensive industries exist, show a large net increase in employment in the period.

A survey based on the 1958 Census of Manufactures of 1,486 plants in 13 major 4-digit SIC industries employing 434,726 production workers showed that, on the average, 54 percent of total production man-hours were used for assembly.[36] This is in close agreement with the estimated percentage stated in section 7 above.

Impact of Automatic Assembly on Future Employment

Because of the number and size of companies producing automatic assembly equipment today, and in recognition of the anticipated growth rates of these companies and allied establishments, no significant employment increases in the assembly equipment industry are foreseen during most of the period under study. With the advent of pro-

[36] *Assembly and Fastener Engineering,* Wheaton, Ill., Hitchcock Publishing Co., n.d.

TABLE 29. CHANGES IN EMPLOYMENT OF ASSEMBLERS AND OPERATIVES, FIVE FABRICATING INDUSTRIES,[1] 25 LARGEST INDUSTRIAL STATES,[2] 1950–60

State [3]	1950		1960		1950 A/O	1960 A/O	Change in A/O, 1950–60
	Assemblers [4]	Operatives [5]	Assemblers [4]	Operatives [5]			
New York	32,759	110,214	50,519	121,734	0.297	0.415	+0.118
Michigan	54,172	152,009	53,552	117,237	.356	.457	+.101
Illinois	31,994	96,417	48,206	92,631	.332	.520	+.188
Ohio	31,889	89,914	46,423	95,676	.355	.485	+.130
California	12,709	32,284	54,460	66,359	.394	.821	+.427
Pennsylvania	20,229	61,554	24,903	73,491	.329	.339	+.010
Indiana	21,564	54,920	28,336	56,138	.392	.505	+.113
New Jersey	16,773	49,340	21,175	53,667	.340	.395	+.055
Massachusetts	12,610	44,151	19,576	47,426	.286	.413	+.127
Wisconsin	11,842	32,015	24,704	36,254	.370	.681	+.311
Connecticut	11,136	36,849	14,929	39,102	.302	.382	+.080
Missouri	6,412	15,839	12,739	20,773	.405	.613	+.208
Texas	4,192	8,923	10,327	16,384	.470	.630	+.160
Minnesota	3,611	10,437	9,404	10,666	.346	.882	+.536
Iowa	4,010	11,422	6,997	12,295	.351	.569	+.218
Kentucky	2,839	6,676	7,476	11,542	.425	.648	+.223
Rhode Island	2,464	10,978	3,073	16,022	.224	.196	−.032
Maryland	3,707	7,992	6,258	11,152	.464	.561	+.097
Tennessee	1,216	4,443	3,394	9,777	.274	.347	+.073
North Carolina	1,057	2,320	3,086	10,394	.456	.297	−.159
Georgia	1,704	5,335	4,992	8,532	.319	.585	+.264
Virginia	705	3,062	2,001	6,282	.230	.319	+.089
Washington	1,108	2,738	1,723	7,285	.405	.237	−.168
Kansas	1,361	2,677	2,703	6,011	.508	.450	−.058
New Hampshire	781	3,055	2,399	5,886	.256	.408	+.152
Total	292,853	855,564	463,355	952,716	.342	.486	+.144

[1] The 5 are SIC code groups 35–39. Fabricated metal parts (SIC 34) is not included. Other assembler-employing industries not included are furniture, locks, nonpowered hand tools, household hardware (including metal doors and screens), and some ordnance materials. The total employment in these industries is estimated to account for 3 percent or less of all-industry assembly labor.

Although the 1957 revision of the *Standard Industrial Classification Manual* shifted many of the industrial classification codes as defined in the 1945 edition, virtually no industries were shifted into or out of code 35 to 39 industries.

[2] As measured by total employment of assemblers and operatives in the 5 defined fabricating industries.

[3] Listed in declining order of total employment in 1960 of assemblers and operatives as defined in notes 4 and 5.

[4] Occupational Classification Code 631 of *1960 Census of Population, Classified Index of Occupations and Industries.* For those industries included in the definition of fabricating, the following assembly occupations are listed: Assembler, assembler (electric motors), assembly girl, assembly leader, assemblyline worker, assemblyman, assembly woman, assembly worker, final assembly lineman, final assemblyman, final assembly worker, major-assemblyline man, phototube assembler, subassembler.

[5] Occupational Classification Code *W*, Operatives and kindred workers (not elsewhere classified). *1960 Census of Population, Classified Index of Occupations and Industries.* Authors' definition inferred by process of elimination of operatives and kindred workers elsewhere classified: semiskilled workers directly employed in machine and process operations. Does not include unskilled laborers, sweepers, janitors, truckers, skilled craftsmen, foremen and kindred workers, such as toolmakers, machinists, maintenance mechanics, millwrights, blacksmiths, inspectors; indirect and service personnel, such as stockers, storeroom clerks, tool-crib attendants, timekeepers, etc.

Change in Assemblers, 170,502=58.22 percent.
Change in Operatives, 97,152=11.36 percent.

SOURCE: U.S. Bureau of Census, *U.S. Census of Population 1950 and 1960, Detailed Characteristics,* Series PC (1)-1D to 53D, Washington, D.C., 1952, 1962.

gramable equipment, still several years in the future, a new industry of some size could evolve. Employment growth might then be spread over assembly machine builders as well as computer manufacturers and machine tool companies who may have entered the field. This type of employment growth could be noticeable to some degree by the end of the period under study. The jobs available in this field will generally require a high order of technical and professional ability and will be concentrated in the areas discussed in section 7 under skill requirements and occupational shifts.

Employment, 1965–75

Given the present state of the art of automatic assembly, and using the assumptions developed in this report, an estimate can be made of the employment effect of this technology over the next 10 years. The estimate is expressed as a bound on the number of workers that would be affected if the establishments now amenable to automatic assembly were to utilize the machines currently available for current production volumes (all expressed in 1963 figures).

Of the 6.60 million workers employed in the six fabricating industries (see table 20), 4.76 million were classed as production workers. Of this latter figure, 1.49 million were engaged in the 37 industries deemed most amenable to automatic assembly (see table 26).

Using the assumption that 50 percent of the production workers employed in the 37 industries are engaged in assembly work, we estimate a total of 750,000 assemblers. The round number of 50 percent is supported by the 50 to 60 percent figure cited in section 7 and the 54 percent figure cited in section 9. The 1960 Census lists 686,754 assemblers under the category of operatives in the experienced labor force.

Assuming further that 50 percent of the assemblers are engaged in subassembly, we estimate 375,000 workers. Since only half of the subassembly work may be amenable to automatic assembly, the labor force which would be directly affected by automatic assembly machines would total 187,500 workers.

There are no quantitative data to indicate the ratio between subassembly and final assembly nor the percent of subassembly amenable to automatic machines. The above estimates are deemed to be reasonable in light of discussions with both the producers and users of automatic assembly machines.

An estimate that up to 50 percent of the assemblers engaged in subassembly could be disemployed by automatic assembly machines establishes a figure of 93,750 workers who would be affected, based upon industry sources.

This calculation can be summarized as follows: 6.25 percent of the production workers in industries amenable to automatic assembly would be disemployed if machines currently available were fully used on current production volumes.

The above disemployment figure is a qualified estimate based upon a static technological and economic situation. It is clear that all the industries and all the establishments within an industry as listed in table 26 are not equally amenable to automatic assembly, nor will the disemployment effects of automatic assembly be equal. It should also be noted that some other industries in some establishments will have production processes that are also amenable to automatic assembly.

The technology of automatic assembly is in the transition stage and many technological developments can be expected within the next decade. These developments will include improved and general purpose machines with a potential application in a widening area of assembly tasks. The disemployment effect of improved machines cannot be anticipated inasmuch as associated changes in design, materials, and manufacturing techniques will be occurring.

The disemployment estimate, it should be emphasized, does not take into consideration processes that are not fully automatic in the sense of section 7, but which may have a cumulative effect equal to or greater than automatic assembly. The estimate does not consider the effects of automation in transfer of materials, packaging, warehousing, inspection, etc., many of which processes are closely associated with assembly.

The cumulative effects of automation in the fabrication industries in which automatic assembly has only begun to have an impact is indicated by an economic review of the 1955–64 period, as mentioned in the conclusion of part 1.

Because of the slow and restricted development of the automatic assembly technology, assembly work will be able to continue to absorb considerable numbers of workers displaced by other aspects of automation. This assumes, of course, increased production to support the demands of a growing population. Increasing employment in assembly activities will overshadow the relatively small inroads of automatic equipment on employment over most, if not all of the next decade.

The most important reason why companies turn to automatic assembly equipment is for labor savings. While other reasons are mentioned, such as quality improvement, greater production, and safety, labor savings are usually the factor that argues most forcibly for automatic equipment. As labor costs increase in the user industries, more of this equipment can be justified. Furthermore, as companies exhaust the economic possibilities of automating machining operations, they naturally turn to the labor-intensive assembly area to apply automation techniques.

Automatic assembly has another important economic rationale. There are companies that have been enabled to survive in the international marketplace due substantially, if not entirely, to automatic assembly and have thus been able to provide work for many who would otherwise be unemployed. Similarly, there are companies that have been able to avoid shifting their assembly operations to other countries where labor is less expensive. Through automatic equipment, they have reduced assembly labor costs and have maintained an employment level higher than it would have been had all assembly operations been removed.

Demand could be stimulated if automatic assembly enables companies to reduce their costs, lower prices and/or improve products. Since automatic assembly today does not significantly affect labor demand, increases in product demand can be reflected in increased employment opportunities.

The succeeding decade, 1975–85, however, should witness more substantial disemployment resulting from automatic assembly machines. This development will be significant because of the number of relatively unskilled workers, women, young people, and members of minority groups who are engaged in assembly work. Automatic assembly will tend to close off an employment absorbing sector of the economy from this group of workers who constitute a growing percentage of the unemployed.

Appendixes

APPENDIX A

The Fabricating Industries

Group 34: Fabricated metal products
- 341 Metal cans
- 342 Cutlery, handtools, and general hardware
- 343 Heating equipment and plumbing fixtures
- 344 Fabricated structural metal products
- 345 Screw machine products, bolts, etc.
- 346 Metal stampings
- 347 Coating, engraving, and allied services
- 348 Miscellaneous fabricated wire products
- 349 Miscellaneous fabricated metal products

Group 35: Machinery (except electrical)
- 351 Engines and turbines
- 352 Farm machinery and equipment
- 353 Construction, mining, and materials handling machinery
- 543 Metalworking machinery and equipment
  - 3541 Machine tools, metal cutting types
  - 3542 Machine tools, metal forming types
  - 3544 Special dies and tools, dies sets, jigs and fixtures
  - 3545 Machine tool accessories and measuring devices
  - 3548 Metalworking machinery, except machine tools
- 355 Special industry machinery
  - 3551 Food products machinery
  - 3552 Textile machinery
  - 3553 Woodworking machinery
  - 3554 Paper industries machinery
  - 3555 Printing trades machinery and equipment
  - 3559 Special industry machinery, not elsewhere classified
- 356 General industrial machinery
- 357 Office, computing, and accounting machines
- 358 Service industry machines
- 359 Miscellaneous machinery

Group 36: Electrical machinery, equipment, and supplies
- 361 Electrical transmission and distribution equipment
- 362 Electrical industrial apparatus
- 363 Household appliances
- 364 Electric lighting and wiring equipment
- 365 Radio and TV receiving sets
- 366 Communication equipment
- 367 Electronic components and accessories
- 369 Miscellaneous electrical equipment and supplies

Group 37: Transportation equipment
- 371 Motor vehicles and equipment
- 372 Aircraft and parts
- 373 Ship and boat building and repairing
- 374 Railroad equipment
- 375 Motorcycles, bicycles, and parts
- 379 Other transportation equipment

Group 38: Instruments and related products
- 381 Engineering, laboratory, and scientific and research instruments and associated equipment
- 382 Instruments for measuring, controlling, and indicating physical
- 383 Optical instruments and lenses
- 384 Surgical, medical, and dental instruments
- 385 Opthalmic goods
- 386 Photographic equipment and supplies
- 387 Watches, clocks, clockworks-operated devices

Group 39: Miscellaneous manufacturing industries
- 391 Jewelry, silverware, and plated ware
- 393 Musical instruments and parts
- 394 Toys, amusements, sporting and athletic goods
- 395 Pens, pencils, and other office and artists materials
- 396 Costume jewelry, buttons, and miscellaneous notions
- 398–9 Miscellaneous industries

APPENDIX B

Definition of Types of Numerical Control

Point-to-point positioning systems provide discrete or point-to-point control, in which the controlled motion is required only to reach a given end point, with no path control during the transition from one end point to the next. The systems are not classified as to movement axes or auxiliary functions. Control is by means of numerically coded programs inserted into the systems on tape or punched card.

Continuous path or contour control systems provide continuous control of the cutting tool by the coordinated, simultaneous motion of two or more axes. Input to the systems is numerical programs inserted by tape or punched card.

Dial or plug-board control systems provide positioning or continuous path operations which are automatically commanded by numerical programs fed into the system by means of dials, plugs, or preset switches, or by playback of prerecorded operations programs.

APPENDIX C

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INDUSTRY PRODUCTIVITY PROJECTIONS

Prepared for the Commission
by the
Bureau of Labor Statistics
U.S. Department of Labor

CONTENTS

Industry Productivity Projections[1]

Introduction

This is a methodological study designed to explore whether plants with high-productivity levels (i.e., technologically advanced plants) can serve as a guide to projecting future productivity increases of an industry. For each industry in this pilot study, data for establishments with above-average productivity levels are analyzed to ascertain whether these plants can be used as estimators of the rate and timing of future productivity change for the industry as a whole. In effect, an early warning system is desired to detect future productivity changes.

Effective planning of manpower programs requires reliable projections of the Nation's labor requirements by industry and occupation. Since the employment requirements of an industry depend on its output and its productivity behavior, data on an industry's past output and past productivity behavior, taken together, serve as a basis for projecting its future employment requirements. In practice, these mechanical projections are modified to conform to any known structural changes occurring in an industry. The future rate of productivity advance may be affected by technological breakthroughs currently being introduced. Although attempts are made to anticipate the spread of technological change and its impact on unit-labor requirements of different industries, there has not been enough study of individual establishment performance to provide a guide for predicting future industry employment requirements.

An industry's productivity depends on the productivity of its component plants. These units typically exhibit wide variation in their productivity (unit man-hour requirements) and productivity movements. The differences may be due to many factors, among which are managerial efficiency, product quality differences, the quantity and efficiency of capital invested per worker; and the skills of the work force.

This study focuses on the plant productivity differences caused by the fact that new technology is often introduced piecemeal into an industry. The leading (or "best") plants adopt the more efficient techniques and the other plants follow them with a lag which depends in part upon the age of their equipment, their actual or anticipated rate of output advance, and competition. At any point of time, a spectrum of techniques may be present in an industry.

The industry's rate of productivity advance can be related to the level of productivity in the "best" (i.e., highest productivity) plants and the rate at which other plants move toward the productivity level of this group. If these two factors are related in a regular (rather than random) way, the relationship may be used to predict the industry's future productivity trends from a knowledge of the current "best plant" productivity.[2]

If time series data show that an industry consistently reached the productivity level which its best plants had reached in X years previously, the pattern provides a predicting device. The productivity level of the current best plants is observed, and the industry average can be projected to reach this level in X years.

This study also analyzes establishment productivity differentials within each industry. The activity of the specific group of plants which were most efficient, and the group which were least efficient, are traced from a given year. If, over time, the former least efficient plants experience a productivity increase greater than the former most efficient plants, they are said to "catch up." The rate of this catching-up effect is measured by comparing the productivity advance of the best plants with that of the least efficient plants in each industry.

While some plants are catching up, others are falling back relative to the industry average. Thus, there may be considerable turnover in the plant productivity rankings, but no change in the overall industry productivity distribution or spread. The least efficient plants, at any point in time, for example, may consistently have unit man-hour requirements twice that of the most efficient plants because the composition of both groups is changing through time.

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[1] This study was prepared by the Bureau of Labor Statistics of the U.S. Department of Labor for the National Commission on Technology, Automation, and Economic Progress. General supervision was provided by Leon Greenberg, Assistant Commissioner for Productivity and Technological Developments, and Lloyd Prochnow, Chief of the Bureau's Division of Productivity Measurement. This study was planned and conducted and the report prepared by Benjamin P. Klotz.

The BLS wishes to acknowledge the generous cooperation of the Bureau of the Census in preparing special tabulations of its basic data. These tabulations were used for developing the measures contained in this report.

[2] The "second-best" group of plants may also be used as a predicting device.

In this study, the industry measure of spread, or dispersion, is the productivity range between the highest productivity and the lowest productivity plants divided by the industry average. If this measure decreases, the relative productivity differences between plants are lessening. This may mean an increase in the transmission speed of new technology from plant to plant; also, it may mean the plants of the industry are becoming more homogeneous.

Summary of Findings

On the basis of the very limited number of industries studied, the findings indicate that:

1. A group of "second-best" plants, with reference to productivity, could be used to project industry productivity 7 years later.
2. The low productivity plants of an industry tend to catch up to the old productivity leaders through time.
3. The speed of this catch up was related to the industry's rate of productivity advance.
4. Despite points two and three above, when *all* plants of an industry were considered there was no tendency for productivity differentials between plants in the top decile and the bottom decile to narrow. However, the plant composition of the top and bottom deciles might not have remained the same.

Best Plant Predictors

Data Sources and Methods

This study is based on the individual establishment records for the industries covered in the Census Bureau Time Series Project. The project includes 25 4-digit manufacturing industries, representing the major portion of Standard Industrial Classification Group No. 33, plus a few industries in various other manufacturing groups. The establishments are classified by the industry code of the 1958 *Census of Manufactures*, based on the 1957 Standard Industrial Classification. Establishments included are those in the *Annual Survey of Manufactures* sample, i.e., nearly all large establishments (those with more than 100 employees in 1958) and a probability sample of smaller establishments. Specifically, the Time Series Project industries are:

SIC No.	*Industry title*
2092	Soybean oil mills
2271	Woven carpets and rugs
2272	Tufted carpets and rugs
2822	Synthetic rubber
2823	Cellulosic manmade fibers
2824	Organic fibers, noncellulosic
2911	Petroleum refining
3011	Tires
3241	Hydraulic cement
3312	Blast furnaces and steel mills
3313	Electrometallurgical products
3315	Steel wire drawing
3322	Malleable iron foundries
3323	Steel foundries
3331	Primary copper
3332	Primary lead
3333	Primary zinc
3334	Primary aluminum
3351	Copper rolling and drawing
3352	Aluminum rolling and drawing
3362	Brass, bronze, copper castings
3391	Iron and steel forgings
3392	Nonferrous forgings
3519	Internal combustion engines
3612	Transformers

Although establishment information exists for these 25 industries over the 1954–61 time period and for 15 of the industries over the 1947–61 time period, the present analysis is restricted to fewer industries because of the disclosure problem—the possibility of identifying a plant by adding or subtracting certain groups of figures. Also excluded were any establishment records which gave evidence of gross unreliability.

In these tabulations, establishments in an industry were ranked according to the ratio of employment to output, i.e., unit labor requirements in a specified year. Decile tabulations were prepared for industries which contained 20 establishments or more (after those with questionable data were dropped from the record); quintile tabulations were prepared for the remaining industries.

A decile tabulation for year "t" was prepared as follows: The plants of a given industry were ranked by their year t unit man-hour requirements; the plants ranking was divided into 10 groups (deciles) on the basis of value added, i.e., the division was performed so that the total value added by the plants in each decile was approximately equal. Quintile tabulations were prepared in the same manner, but the plants were split into only five groups. Generally, the deciles (or quintiles) contained an unequal number of plants. Also, their aggregate value added was different due to overlap establishments (those which would fall partly in two deciles or quintiles). These were placed in the decile or quintile in which the major part of their value added lay. So the value added in a given decile (or quintile) may vary from the expected 10 percent (or 20 percent). Decile tables for which the value added in any "decile" was less than 6 percent or more than 19 percent of the industry total were excluded as being not truly representative of a decile breakdown. Similarly, the quintile tables have been excluded if the value added in the "quintile" was less than 11 percent or more than 39 percent of the industry total.

Because of the restrictions described above, the analysis for 1954–61 is limited to 17 industries. For these 17 industries, decile tabulations are available for 10 industries and quintile tabulations for 7 industries. Similarly, the analysis for 1947-61 is limited to 9 industries. For these nine industries, decile tabulations are available for four industries and quintile tabulations for five industries.

The terms output, employment, productivity, unit man-hour, and plant used in this study are defined as:

1. Output=real adjusted gross production=value of shipments plus net change in inventory and work-in-process, adjusted for price change. (Unpublished BLS price indexes were used for this purpose.)
2. Employment=production worker man-hours, i.e., PWMH.
3. Productivity=output divided by employment.
4. Unit Man-Hours=employment divided by output, i.e., UMH.
5. Plant=establishment (as opposed to "firm").

Problems

There are several problems involved in this approach. The "best plants" (those appearing in the top decile of a plant productivity ranking) are identified on the basis of their reported output and employment for a given base year. They are not deduced from the average behavior of a group of plants through time. To the extent that the base year plant data are not typical or accurate, classification errors can arise. However, as explained subsequently, it appears that this is a minor problem.

The high productivity plants may not be producing the same commodity-mix as the other plants, even though they are grouped within the same 4-digit industry. The "best" plants could be highly specialized and as such not typical of the industry. Thus, they would be fundamentally different from the rest of the industry and their predictive value would be impaired.

These reasons necessitated selection of a group of "second best" (second decile) plants, also, for use in predicting the productivity level of an industry. It can be argued that this group of plants is sometimes more likely to be the real group of best plants than is the first decile group which only appears best.

The time series information seems too short to establish a reliable relationship between the best (or second best) plants at time t and the industry average at time t+n. The time series comparison runs at most from 1947 to 1961. If industry productivity in year 1961 reached the best plant level of 1947, we would say there was a 14-year lag in this particular case. But it would be hazardous to project this relationship into the future on the basis of only one observation. Similarly, there are only two observations if there is a 7-year lag in a specific industry, 1947-54 and 1954-61.

This method, then, does not necessarily replace the simple trend projection of industry productivity. It can serve as a supplementary approach to the familar trend method, perhaps serving to indicate significant changes in longrun productivity trends.

Findings

The attempt to predict industry productivity by examining a current group of efficient plants has proven encouraging, but at this stage, somewhat inconclusive. Because of disclosure problems[3] the array of 25 industries was reduced to 17, and comparable records were available for only 9. It was possible to compare the high productivity decile of plants with subsequent industry behavior in only four cases. Five more industries were examined but it became necessary to resort to quintile analysis, with some loss of precision.

For each of four industries, only two observations were obtained on the relation between the plants in the top efficiency decile, referred to as decile 1, and the industry average 7 years later. That is, 1947 decile 1 productivity was compared with 1954 industry productivity and then 1954 decile 1 productivity was compared with 1961 industry productivity (table 1). Generally, the relationships do not appear too stable. The results are even less conclusive when top quintile plant unit labor requirements (ULR) are compared with the industry average 7 years later.

However, the results are much more consistent when the productivity of the second decile plants (the so-called "second best" group) is compared with the industry average 7 years later. Table 2 shows remarkable consistency between the two 7-year lag relations for all four industries. For example, after viewing industry number 17, one might feel justified in predicting that 1968 industry ULR would exceed the 1961 second decile ULR by 10 percent. If further studies support these findings—that industry UMH equal decile 2 UMH in about 7 years—then a large productivity growth will be anticipated if decile 2 is low relative to the industry average. For example, if decile 2 UMH is about 30 percent below industry UMH, about a 5-percent annual increase in productivity might be expected for the following 7 years. Once again the predicting device seems less reliable when a quintile breakdown is used.

At this point, the "best plant" predicting method needs more research. The second productivity decile seems to work well, but it has been applied to only four industries and two time pe-

[3] A decile often contained only two establishments and was suppressed. Also, certain manipulations of decile and/or industry totals would have resulted in the disclosure of individual plant information.

TABLE 1. RATIO OF INDUSTRY UNIT MAN-HOURS AT TIME t TO BEST PLANT UNIT MAN-HOURS AT TIME t−7

Industry	1947 ranking	1954 ranking	1947 ranking	1954 ranking
	Industry ULR, 1954	Industry ULR, 1961	Industry ULR, 1954	Industry ULR, 1961
	Decile 1 ULR, 1947	Decile 1 ULR, 1954	Quintile 1 ULR, 1947	Quintile 1 ULR, 1954
1	—	—	[1] 1.00	0.69
2	—	—	1.37	1.31
3	—	—	1.00	1.25
4	1.38	1.20	—	—
5	1.39	1.27	—	—
6	1.32	1.41	—	—
7	—	1.70	—	—
8	—	—	—	1.18
9	—	1.71	—	—
10	—	1.45	—	—
11	—	—	2.20	1.92
12	—	—	.84	[1] .94
13	—	—	—	.78
14	—	3.14	—	—
15	—	1.73	—	—
16	—	1.49	—	—
17	1.32	1.24	—	—

[1] Decile 2 divided by industry average ULR.

NOTE: Dashes indicate no data or data do not meet publication criteria.

TABLE 2. RATIO OF INDUSTRY UNIT MAN-HOURS AT TIME t TO SECOND-BEST PLANT UNIT MAN-HOURS AT TIME t−7

Industry	1947 ranking	1954 ranking	1947 ranking	1954 ranking
	Industry ULR, 1954	Industry ULR, 1961	Industry ULR, 1954	Industry ULR, 1961
	Decile 2 ULR, 1947	Decile 2 ULR, 1954	Quintile 2 ULR, 1947	Quintile 2 ULR, 1954
1	—	—	1.00	0.56
2	—	—	1.05	1.00
3	—	—	—	.93
4	1.00	0.92	—	—
5	1.02	1.05	—	—
6	1.03	1.04	—	—
7	—	1.16	—	—
8	—	—	—	.80
9	—	—	—	—
10	—	1.26	—	—
11	—	—	1.50	1.39
12	—	—	.69	.94
13	—	—	—	.74
14	—	1.29	—	—
15	—	—	—	—
16	—	1.19	—	—
17	1.10	1.10	—	—

NOTE: Dashes indicate no data or data do not meet publication criteria.

riods. The Census Bureau is continuing its Time Series Project and more information will be available in the future.

Time did not permit examining the existence of a 7-year lag each year—that is, a correlation between decile 2 productivity at time t and industry productivity at time t+7, with t running from 1947 to 1954. This would use the Census Bureau information more extensively and might be made a followup study.

Catch-Up Analysis—Efficient Turnover of Establishments

The establishments in nine industries were ranked by their 1947 unit labor requirements (ULR) and split into decile or quintile groupings. The plants in the first and last decile (or quintile) were identified and their ULR behavior was traced through to 1954, 1957, and 1961. In most of the nine industries, the group of plants with the highest initial ULR (low productivity) experienced rapid and persistent ULR declines during 1947–61. The ULR behavior of the initial low ULR (high productivity) plants was not as dramatic. Thus, there was a definite tendency for the initial group of low productivity plants to persistently "catch-up" through time with the initial group of high productivity plants when the plants in the initial distribution (top and bottom deciles) are held constant. However, when the decile distribution of specific plants is allowed to change over time, the spread between the top and bottom decile tends to remain stable.

During 1957–61, the productivity differences between the two groups of plants fell most rapidly in the industries which experienced the greatest productivity advances. The correlation was 0.93.[4] When the narrowing productivity differential was related to the industry's rate of output advance, the correlation fell to 0.58. These figures are not derivable from table 3, being based upon the 1954–61 industry list rather than the 1947–61 list.

The catch-up behavior can be split conceptually into short-run and long-run causes. The short-run refer to the temporary or erratic factors which might influence the 1947 productivity ranking of plants. As stated previously, data errors or a temporary output fluctuation may cause some plants to be ranked abnormally high or low with respect to productivity. However, this probably did not occur to any significant degree in this study because the initial low productivity plants moved steadily closer to the original group of leading plants during the 1947–61 period.[5] The catch-up then seems to be due to fundamental economic forces rather than temporary aberrations or data errors.

The rather persistent productivity catch-up of the lowest decile plants could be due to a relative improvement in quality of management, product, equipment, training of employees, or in the amount of capital invested per worker.

The Census Time Series Study does include data on gross book value of capital, capital expenditures, depreciation, and degree of plant specialization on its major product. A change in any one of these items could affect plant productivity. The group of low productivity plants may increase

[4] Spearman coefficients of rank correlation based upon nine industries were computed. Other time periods lacked enough industry observations to derive meaningful results.

[5] Had there been a rapid change in the productivity ranking of an industry's plants between 1947 and 1954 and then little change between 1954 and 1961, one would be tempted to claim that the 1947 ranking was incorrect and that the 1947–54 catch-up was largely spurious.

the quantity and quality of their equipment per worker in order to remain competitive. An attempt to verify theories of this type has not been attempted in this study, but further work is planned to identify the factors associated with establishment productivity changes. A multiple regression approach is envisioned, relating percentage change in plant productivity to changes in plant size, capital per man-hour, and other factors.

TABLE 3. COMPARISON BETWEEN PLANTS OF THE LOWEST AND HIGHEST PRODUCTIVITY DECILES IN 1947: PERCENT OF 1947 PRODUCTIVITY DIFFERENCE REMAINING AT YEAR t

Industry	t=1954	t=1957	t=1961
1	0.40	0.40	0.24
2	.91	.34	.28
3	.51	.31	.14
4	.47	.45	.49
5[1]	1.10	.86	.15
6[1]	.75	.68	.44
7[1]	.52	.56	.19
8[1]	.56	.60	.33

[1] The first and fifth quintiles are compared instead of the first and tenth deciles.

Frequency Distribution of Plant Productivity

There seemed to be no tendency for plant productivity differentials to narrow between 1947 and 1957. The ratios of table 4, analogous to coefficients of variation, are formed by dividing the decile (or quintile) productivity range of an industry by its average productivity. This statistic, call it "S", decreased between 1947 and 1957 for five of the nine industries, but only the first industry experienced a uniform decline. These five industries generally did not have above-average productivity or output increases.

TABLE 4. ESTABLISHMENT PRODUCTIVITY RANGE AS A PERCENT OF INDUSTRY PRODUCTIVITY[1]

Industry	1947	1954	1957	Industry	1947	1954	1957
1[1]	1.50	1.33	1.31	5[2]	1.19	.71	.92
2[1]	.94	1.43	.89	6[2]	.72	.97	.81
3[1]	.94	1.04	1.01	7[2]	.76	1.07	.98
4[1]	.81	.83	.76	8[3]	2.79	3.00	2.38
				9[3]	.29	.75	.77

[1] Each year the productivity spread between the high and low decile plants is standardized by dividing by the industry average.
[2] The second and fifth quintiles are used for comparison rather than the first and tenth deciles.
[3] The first and fifth quintiles are used for comparison.

APPENDIX

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