COMPUTER-INTEGRATED MANUFACTURING HANDBOOK

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COMPUTER-INTEGRATED MANUFACTURING HANDBOOK

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Preface

Manufacturing has entered the early stages of a revolutionary period caused by the convergence of three powerful trends:

- The rapid advancement and spread of manufacturing capabilities worldwide has created intense competition on a global scale.
- The emergence of advanced manufacturing technologies is dramatically changing both the products and processes of modern manufacturing.
- Changes in traditional management and labor practices, organizational structures, and decision-making criteria represent new sources of competitiveness and introduce new strategic opportunities.

These trends are interrelated and their effects are already being felt by the U.S. manufacturing community. Future competitiveness for manufacturers worldwide will depend on their response to these trends.

Based on the recent performance of U.S. manufacturers, efforts to respond to the challenges posed by new competition, technology, and managerial opportunities have been slow and inadequate. Domestic markets that were once secure have been assailed by a growing number of foreign competitors producing high quality goods at low prices. In a number of areas, such as employment, capacity utilization, research and development expenditures, and capital investment, trends in U.S. manufacturing over the last decade have been unfavorable or have not kept pace with major foreign competitors, such as Japan. There is substantial evidence that many U.S. manufacturers have neglected the manufacturing function, have overemphasized product development at the expense of process improvements, and have not begun to make the adjustments that will be necessary to be competitive.

These adjustments represent fundamental changes in the way U.S. manufacturers perceive their competitive advantages, devise competitive strategies, and manage and organize their operations. One response

that is beginning to gather momentum among U.S. manufacturers is the implementation of computer-integrated manufacturing. Indeed, technology, wisely applied, can improve costs, quality, flexibility, and responsiveness, but the effects of technology on these areas can be complex. Trade-offs between improving flexibility and responsiveness on the one hand and reducing costs on the other will continue; technologies that are poorly applied may not have the effects intended; and many barriers to their smooth operation remain. Effective implementation of new technology demands a clear definition of the business's strategy and a clear understanding of the role of advanced technologies in supporting that strategy. Managers must recognize that many of the perceived advantages of new technology can be achieved with new management techniques, more effective planning, better coordination across corporate functions, efforts to reduce set-up times and speed changeovers, and simplified part designs to enhance producibility. Having made effective operational and organizational changes, the company can eliminate many of the problems that are often associated with the introduction of new technologies. Effective efforts in these areas also should help managers focus new investments on appropriate technology that can produce dramatic benefits.

These required organizational changes, however, will be difficult for many manufacturers to implement. They require creative initiatives from managers, the cooperation and involvement of employees, and major changes in the relationships at every level of the manufacturing corporation. A fundamental cultural and attitudinal shift will be required on the part of both workers and managers. Manufacturing will need to be thought of as a system, with extensive integration, cooperation, and coordination between functions, to achieve competitive goals. Flatter organizational structures are likely to become the norm and traditional hierarchical relationships are likely to fade as the distinctions between managers and workers blur. Workers will have more responsibility and greater job security and be more active participants in the manufacturing system.

Because the successful implementation of this cultural revolution in the factory depends on thousands of individual initiatives, change is likely to be gradual. In many cases, there will be strong resistance from both managers and workers who have a stake in traditional practices and structures. However, as competition in the new environment intensifies and the requirements to maintain competitive advantage with quality manufactured goods become clear, the benefits and the necessity of implementing these changes will be increasingly apparent.

These changes imply that the factory will provide a much different working environment and play a different role in the macroeconomy.

For example, manufacturing will provide fewer job opportunities for unskilled and semiskilled workers, but the jobs that will be created are expected to require greater amounts of skill and training and thus be more challenging and rewarding. Many manufacturers will have sufficient flexibility built into their production processes to be less affected by shifts in demand, which could moderate business cycles substantially.

These and other effects will require that government officials and the general public adjust their image and expectations of manufacturing. Although the technological and managerial changes necessary for future competitiveness will be the responsibility of the private sector, the government can play an important role in encouraging and supporting these private initiatives. Policymakers must recognize the continuing importance of manufacturing, the need for changes to ensure future competitiveness, and the many repercussions government policies have on the ability of U.S. manufacturers to meet competitive challenges. In addition, some specific government activities, in trade, education, research, and defense, will be affected by developments in manufacturing and will need to adapt accordingly.

V. Daniel Hunt
Springfield, Virginia

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The information in the *Computer-Integrated Manufacturing Handbook* has been compiled from a wide variety of authorities who are specialists in their respective fields.

The following publications were used as the basic technical resources for this book. Portions of these publications may have been used in the book. Those definitions or artwork used have been reproduced with the permission to reprint of the respective publisher.

Computerized Manufacturing Automation: Employment, Education, and the Workplace (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-CIT-235, April 1984).

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The preparation of a book of this type is dependent upon an excellent staff, and I have been fortunate in this regard. Special thanks are extended to Janet C. Hunt and Donald W. Keehan for research assistance and to Margaret W. Alexander for the word processing of the manuscript.

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Part I

System Fundamentals

Chapter 1

The Need for Computer-Integrated Manufacturing

For U.S. manufacturing, an extended period of world dominance in manufacturing innovation, process engineering, productivity, and market share has ended. Other countries have become leaders in certain industries, the U.S. market is being flooded by manufactured imports, and U.S. manufacturers are faced with relatively low levels of capacity utilization and declining employment. The reasons for this fundamental change are complex. Improved capabilities and competence of foreign manufacturers are partly responsible. Either government interference or the lack of government support has been blamed. Cultural disadvantages are often cited. Many economists explain the relative decline of U.S. manufacturing simply as economic evolution, with the United States moving toward a service economy. These and other factors have been held responsible for the relative decline of U.S. manufacturing, and all are legitimate partial explanations. The truth remains, however, that U.S. manufacturing is not performing as well as that of many foreign competitors and has lost competitiveness in many industries. Regardless of why the environment has changed, the managerial practices, strategies, and organizational designs applied by U.S. manufacturers have not adapted sufficiently to the changed competitive environment, and, consequently, U.S. manufacturing has not been as successful as that of other countries.

The term competitiveness is subject to a variety of definitions. In simplest form, an industry is competitive if the price, quality, and performance of its products equal or exceed that of competitors and provide the combination demanded by customers. International competitiveness is somewhat more complicated because price is heavily influenced by exchange rates, which cannot be controlled by an individual producer. Many economists would claim that the recent high rate of the dollar

has been responsible for any lost competitiveness of U.S. manufacturing, and recent adjustments to the dollar will restore competitiveness. This may or may not be true, however, because exchange rates are only one determinant of product price, and price is only one determinant of competitiveness. Price is also determined by production costs, and quality and performance, including innovation, unique or superior design, and reliability, are in many cases more important determinants of competitiveness than price. If U.S. manufacturers can produce high quality goods with less labor, materials, overhead, and inventory than foreign producers, then competitive production can be ensured. These are the areas in which U.S. manufacturers have lagged—improvements in the use of these resources, as well as product quality and performance, are the requirements for improved competitiveness.

These changes in relative manufacturing strength are occurring at the same time that many technological innovations promise to revolutionize products and processes in manufacturing. Just as major technological breakthroughs spurred industrial development in the mid-eighteenth century (steam power, new engine-driven machinery) and the development of the modern factory system in the late nineteenth century (electricity, the telephone, and mass production techniques), current breakthroughs in electronics, materials, and communications are creating another revolution in manufacturing. Just as earlier changes forced new directions in manufacturing management, production strategies, and national policies for maximizing competitiveness, the competitive and technological changes affecting manufacturing today should create new goals, new priorities, and new expectations in U.S. industry. Many manufacturing managers and national policymakers, however, have been slow to recognize the implications of these developments. U.S. manufacturing is in danger of being unprepared to compete in the coming age, a failure that would cause rapid erosion of the nation's manufacturing base.

Effective response to the changes in manufacturing depends on a clear understanding of the new environment. Although specific developments are difficult to predict with certainty and the types of changes will vary tremendously among industries, likely trends can be identified. Competition will continue to increase both at home and abroad. New products will proliferate; many products will have shorter life cycles and development cycles. Some industries will have smaller production volumes, with more product customization and variety. New technologies, especially those based on microprocessors, will optimize control of the production process and offer entirely new capabilities. Fewer production workers and middle managers will be needed, but the remaining jobs will require higher skill, more technical knowledge, and greater re-

sponsibility. Managers will need to manage manufacturing as a system, basing decisions on new, nontraditional indicators. Direct labor costs will decrease significantly, and the costs of equipment, materials, distribution, energy, and other overhead will grow in importance. Quality, service, and reliability will receive much more emphasis as determinants of competitive production.

These trends indicate that competition, both international and domestic, will be more intense and that the factors determining competitiveness will differ substantially from past experience. Strategies and priorities designed to enhance competitiveness in the mid-twentieth century will be far less effective in the future. The new manufacturing environment will be sufficiently familiar to permit many firms to continue to use traditional approaches, but these firms will lose market share, profits, and the ability to compete. In the new environment, it will not be sufficient to do the same old things better. Companies will need to adopt new management techniques, organizational structures, and operational procedures to strengthen their international competitiveness. Government policies must also ensure that U.S. manufacturers receive the infrastructural support they will need to compete effectively.

A Historical Perspective on U.S. Manufacturing

For much of the twentieth century, U.S. manufacturers were unchallenged in an environment in which conservative approaches to both process technology and managerial techniques produced successful results. Foreign competition was minimal, the vast domestic market encouraged product standardization and economies of scale, and the preeminence of Yankee ingenuity was unchallenged. Companies modified strategies and processes in minor ways in response to shifting economic circumstances, but mostly the system worked and they had little incentive to change. The relative stability of the manufacturing environment was unsustainable, however; a series of changes has gradually converted the traditional strategies to handicaps.

One change has been the way companies justify new investment in manufacturing. During the 1950s and 1960s, the emphasis in manufacturing was on providing substantial additional plant capacity that was needed just to keep up with market growth. The addition of capacity provided the opportunity to incorporate process improvements that otherwise were rarely implemented. Beginning in the early 1970s, the rate of growth slowed (Table 1–1), in many cases eliminating the need

Table 1-1. U.S. Manufacturing Output[a]

Average Annual Percentage Change

Period	Total	Durable Goods	Nondurable Goods	As a Percentage of Total Output[b] (average)
1950-1983	3.1	3.0	3.1	24.4
1950-1973	4.0	4.0	4.0	24.6
1973-1983	0.9	0.7	1.1	24.1
Slowdown	3.1	3.3	2.9	0.5

[a]Gross product originating in manufacturing in constant dollars.
[b]Gross national product in constant dollars.

Source: U.S. Bureau of Labor Statistics, 1985.

for additional capacity. Companies needed to develop new justifications for reinvestment in manufacturing, which many have been slow to do.

Another major change in the manufacturing environment was in the process of developing and implementing new innovations. The first Industrial Revolution in the 1800s produced a series of significant innovations in process and product technologies that represented an integration of several types of technologies. In contrast, during the early to mid 1900s, manufacturers, except perhaps for electronics and chemicals manufacturers, increasingly refined proven technologies rather than developing and integrating new and diverse technologies to accomplish, or even eliminate, traditional tasks. This apparent trend toward a more stable, conservative approach to process technology in a broad range of U.S. industries combined with a variety of other factors—such as changing labor demographics, higher energy prices, and lower expenditures on research and development—to cause a shift toward more modest improvements in productivity.

U.S. industries in which new technology did seem to offer great potential focused predominantly on product engineering at the expense of process engineering. (The semiconductor, chemical, and biotechnology industries are exceptions since most of the breakthroughs in their products depend on breakthroughs in process capabilities.) Since manufacturers had their hands full simply adding capacity of a known type, they saw no pressing need to add new process technologies at the same time. Consequently, many U.S. firms spent incremental dollars on product technology and very little on new process technology. Generally speaking, U.S. manufacturers left process development to equipment suppliers and allowed their own skills at such development—and its link with product technologies and product quality—to decline.