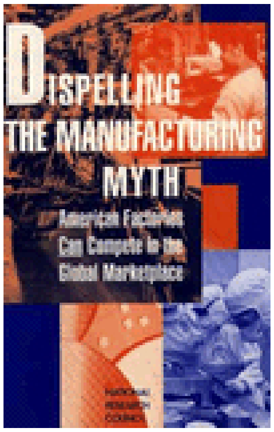

Dispelling the Manufacturing Myth: American Factories Can Compete in the Global Marketplace

Committee on Comparative Cost Factors and Structures in Global Manufacturing, National Research Council

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DISPELLING THE MANUFACTURING MYTH

American Factories Can Compete in the Global Marketplace

Committee on Comparative Cost Factors and
Structures in Global Manufacturing
Manufacturing Studies Board
National Research Council

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Finally, the committee acknowledges the work of the staff of the Manufacturing Studies Board. This report would not have been possible without the hard work and patience of Tom Mahoney, Mike Witmore, Ted Jones, and Verna Bowen.

Preface

The Committee on Comparative Cost Factors and Structures in Global Manufacturing began its deliberations in the fall of 1989. With the generous support of the U.S. Department of Defense, the committee undertook an examination of manufacturing costs in domestic and offshore factories to provide insight into the factory location decision-making process. There was at the time, and continues to be, considerable discussion of the concept of a "level playing field" in international trade—that is, the idea that foreign manufacturers and offshore factories have inherent cost advantages relative to U.S. manufacturers for a number of reasons: not only are labor costs lower, but factors such as health benefits, pensions, environmental compliance, and liability insurance pose far less of a burden to foreign manufacturers than they do to their U.S. counterparts. The committee's objective was to review these various costs in a number of industries that face strong foreign competition to determine the extent to which different cost factors and structures in different locations affect manufacturing costs.

Such an objective proved to be too ambitious. Information on production costs simply is not available on a sufficiently disaggregated basis to perform the broad-based analysis intended by the committee. Consequently, the committee relied heavily on the data that were available and focused on the factors that determine factory site location decisions. Its analysis of international cost differentials in consumer electronics is based on internal corporate data provided by AT&T and Toshiba. The committee's examinations of the semiconductor and automobile industries are based more on the committee's experiences in and knowledge of those industries than on actual cost data, which were not available. Because little actual cost data were available from these industries, these analyses describe the factors that determine manufacturing efficiency and factors other than cost, such as trade barriers and local content requirements, which often determine where production is done.

In all the industries examined, the committee found that, with effective management of the total manufacturing system, manufacturing in the United States can be cost competitive with offshore production and, further, can provide significant advantages in staying abreast of and responding rapidly to changing customer demands. The committee recognizes, however, that other factors besides cost drive site selection decisions and that globally dispersed production facilities offer U.S. manufacturers advantages in learning new practices, gaining access to new technologies, and responding to foreign customers effectively.

In Chapter 4 the committee describes a decision model that captures its findings in a general context. Many factors determine the attractiveness of different countries for manufacturing. They range from external factors such as exchange rates, trade barriers, and government subsidies to internal variables such as the labor intensity of the manufacturing process, location of suppliers, and relations with the firm's other plants. Site selection becomes a complex decision, typically unique in each case. Both managers and government policymakers need to recognize this complexity and strive to make the United States an effective base for manufacturing.

LAURENCE C. SEIFERT, CHAIRMAN

COMMITTEE ON COMPARATIVE COST FACTORS AND STRUCTURES IN GLOBAL MANUFACTURING

Contents

DISPELLING THE MANUFACTURING MYTH

Executive Summary

Over the past three decades, U.S. manufacturers have lost market share in several industries they once dominated. A common explanation has been that the United States is no longer a competitive location for manufacturing: wages and benefit costs are too high, American workers are too inflexible (with respect to work rules and production practices), and capital costs too much for U.S. manufacturers to invest as much as their foreign counterparts.

The Committee on Comparative Cost Factors and Structures in Global Manufacturing was formed to examine the relationship between manufacturing costs and global factory site selection decisions. The study was motivated by the argument that the United States has become—or is destined to become—a high-cost environment for manufacturing and therefore must specialize in high-value products. Although the committee recognizes that all the activities that comprise the product realization process—design, engineering, purchasing, production, marketing, distribution, and sales—determine the full costs of bringing a product to market, manufacturing costs incurred in the factory are typically what affect decisions to shift production offshore. These costs are, therefore, the focus for the committee's analysis.

This "high-cost environment" argument has become common wisdom because it is partially based on fact and historical precedent. It is true that a variety of direct-labor-intensive manufacturing processes—typically assembly operations—were moved offshore in the 1960s and 1970s because they could be done less expensively. In the 1980s, however, the rationale for offshore manufacturing began to change. Access to lower-cost direct labor continues, but its importance is waning—first, because direct labor is declining as a proportion of total manufacturing costs and, second, because manufacturers are finding that other factors besides cost affect their competitiveness. Manufacturers have begun siting factories offshore to gain access to markets, as well as access to manufacturing processes, skills, technologies, or components unavailable in the United States.

Today, effective onshore/offshore location decisions are part of an integrated business strategy designed to maximize total business potential. Location is assessed not just in terms of cost reduction but also for opportunities to increase business. A variety of variables are considered, many of which do not show up on a profit-and-loss statement (see Figure 1-4, strategic business decisions model). Determinants of cost-competitive production have as much to do with process control, product quality, supplier and customer relations, and time to market as with wage rates and capital costs.

These new considerations in site location decisions reflect two key developments, one in manufacturing, the other in the market. With respect to the former, effective manufacturing is managed as an integrated process. Product and process design, the transformation of materials and information into products, customer service, product support, and marketing are treated as interconnected functions in a cycle that must be continuously improved. Manufacturers are put at a disadvantage if management focuses solely on minimizing input costs defined in narrow accounting terms (e.g., minimizing labor costs by seeking low wages). Instead, today's manufacturer must consider how site selection decisions will affect its ability to improve cycle time, to drive down defects, and to add value in new ways that respond to or create customer demand.

The appearance of these changes in manufacturing coincides with the appearance of a new kind of customer. Consumers now demand products of superior quality that are introduced and delivered in a timely way. Further, it is increasingly essential that products be tailored to unique or changing customer preferences. To satisfy these new demands, manufacturers must consider whether a prospective site will give them direct access to customers so that they can respond to changing demands quickly. The ability to link a site to other operations and to suppliers is important, too, since the total manufacturing enterprise must be carefully coordinated if cycle time and quality defects are to be driven down.

The committee's analysis of three industries illustrates how site location decisions are affected by changing technology, customer expectations, and sources of competition in manufacturing businesses. In consumer electronics, semiconductors, and automobiles, manufacturers must consider a wide range of variables when deciding where to manufacture.[1] For example, the AT&T data described in Chapter 2 shows that the costs of materials—not labor—are the primary driver of onshore/offshore cost differentials for the products studied. Further, the Toshiba study demonstrates that the United States is actually a "low-cost" manufacturing location compared to Japan at recent prevailing exchange rates. Perhaps more importantly, the Toshiba study confirms that market access, almost regardless of manufacturing costs, is typically what draws foreign manufacturers to the United States.

While the consumer electronics industry demonstrates that labor costs are not the primary consideration in manufacturing location decisions, the semiconductor industry analysis (Chapter 3) illustrates the relative insignificance of input cost differentials in the face of other factors, such as cycle time, throughput, and yields. The significant competitive factor in semiconductor manufacturing is not the comparative size of the initial outlay for a facility (which is huge and growing but similar throughout the industry), but a firm's ability to maximize the returns on that investment through capacity utilization. Skilled workers, good designs, and high-quality equipment and materials are prerequisites for the necessary level of process control, but effective process management is essential. Consequently, the main criteria for site selection of wafer fabrication facilities are (1) market access—there must be sufficient demand to justify expensive capacity expansion and a need to locate near demand centers, for quick response or to overcome trade barriers, and (2) access to skills to ensure that the investment in plant and equipment is justified by rapid product realization and rapid progress in yield improvement.

Finally, the automobile industry analysis (Chapter 4) demonstrates that the United States remains an attractive location for effective manufacturing and illustrates the rapid changes taking place in understanding and managing manufacturing costs in a traditional high-volume mass production environment. Lean production, the new approach to high-volume manufacturing pioneered by Japanese firms, is a systemic approach to manufacturing that reduces total costs and cycle time while increasing quality and flexibility.[2] Lean production emphasizes continuous improvement in the total manufacturing system. Instead of focusing on traditional accounting categories such as labor cost and number, materials cost, or overhead, lean producers concentrate on other cost drivers, such as minimizing work in process, inventories, and materials waste. Continuous improvement in the manufacturing system is achieved through worker empowerment, essentially recognizing that workers themselves know the best way to perform their jobs and that they will be innovative in applying improvements if unconstrained by strict work rules. This approach to manufacturing represents a fundamental change in the nature of mass production work and therefore is not easy to implement. Lean production, however, has been successfully implemented in the United States by both American and Japanese producers. It is, therefore, a completely "portable" competitive advantage. The automobile industry analysis demonstrates that cost competitiveness can be more a matter of managing costs effectively than of finding environments where local cost structures offer an input cost advantage.

Depending on a firm's business and market strategy, different factors will influence where it locates its manufacturing facilities (i.e., it will find different attributes attractive). These attributes can be divided into three categories:

- Access to low-costs
- Access to skills, technology, and capabilities
- Access to markets

Based on its examination of siting decisions in the three industries chosen, the Committee found that access to low labor costs should be a primary consideration only in a limited number of decisions. Most of the decisions studied by the committee were driven by other factors, such as access to markets, lower cost of materials, specific product or process technologies, and proven capabilities in high-quality production by suppliers. This is not surprising. Because of changes in both the nature of manufacturing and the demands of consumers, it is essential that a firm consider access to markets, proximity to customers, and the benefits of competing against world-class competitors, as well as access to worker skills, components, or technologies, when siting a facility.

The committee finds that the U.S. manufacturing environment offers several of the features that competitive manufacturers find particularly attractive. The large market of relatively affluent consumers, the pool of skilled workers, a strong base of technologies and components, and a national tradition of innovation are all highly attractive attributes. Further, innovative management systems such as lean manufacturing can flourish in this country. This environment will likely continue to attract manufacturers in all three of the industries studied.

There are, however, aspects of the U.S. manufacturing environment that deserve attention from government and industry alike. The industrial infrastructure—the supplier base, technology base, and work force skills—must be enriched continuously if the United States is to remain attractive. Protectionist policies must not be allowed to undermine the vibrancy of the United States as a "state-of-the-art market"—one in which a variety of world-class foreign and domestic manufacturers compete for the business of highly demanding consumers. Such a market is a spur to improvement for U.S. firms and a magnet for foreign ones, as well as a fundamental condition for long-term growth in the American standard of living.

To ensure that the U.S. manufacturing environment remains attractive, the committee offers several recommendations to both industry and government. Industrialists should:

1. Accept responsibility for losses in competitiveness instead of blaming them on exogenous cost factors. Managers

must understand that they have the power to stimulate dramatic improvements in manufacturing effectiveness. External cost factors need not have a significant impact—in most instances—on a firm's ability to produce competitively. The cost advantages of offshore locations can often be offset by strong, effective management of a skilled work force keeping appropriate manufacturing process technology in tight control.

2. Understand that global competition has raised the performance standards required for manufacturing success; thriving firms need to perform as "best in class" in their respective markets. To do so, firms must not let outdated notions of cost drive business decisions (i.e., focusing on labor), they must collaborate with and learn from domestic and foreign competitors, and they must educate and train managers and production workers so they can achieve lean production.
3. Take advantage of natural U.S. advantages: (a) a large and relatively open market comprising innovative, creative, risk-taking manufacturers and (b) an excellent university system capable of achieving tremendous intellectual advances and providing highly skilled personnel for world-class manufacturing.
4. Constantly strive to provide customers with higher value-added—embracing both technological and methodological sources of value. This means opening markets at home and abroad so that new technologies and methodologies can be accessed and R&D costs can be amortized. U.S. firms can push new value frontiers only if they do it globally.

Government, on the other hand, must do its part in fostering the conditions necessary to ensure that the United States remains an effective location in which to manufacture. Of particular relevance to companies' decisions regarding where to produce is the knowledge that markets will be open to U.S. exports and that necessary skills will be available for competitive production. Policymakers should:

1. Foster a favorable environment in the United States for competitive global manufacturers, foreign and domestic, by maintaining the macroeconomic conditions necessary to sustain a state-of-the-art market. The strong competition and healthy demand needed for such a market require stability and predictability

in prices, tax regimes, and trade policies to allow confidence in decisions with long time horizons.

2. Avoid restrictions on foreign direct investment, joint ventures, and other sorts of interfirm cooperation or technology flows that would inhibit U.S. manufacturers' access to skills, knowledge, and technology, whatever the source. Fight similar restrictions abroad where they limit U.S. exports, direct investment, and technology access.
3. Encourage and support work force education and skills mobility. A skilled, educated work force is a critical component of a state-of-the-art market. The United States must maintain the necessary investment in its educational infrastructure to ensure that the supply of courses, materials, and instructors is sufficient to meet demand, not just for new graduates but for much of the existing work force.
4. Resist pressures from the business community to protect the status quo. U.S. business failures are not necessarily market failures requiring government remediation.

Given appropriate incentives, skills, resources, and management of manufacturing as an integrated system, U.S.-based production can be not only cost competitive but also competitive in quality, features, and timeliness. Both American and foreign-owned companies have proven it.

NOTES

1. These industries were chosen because they have been central to the debate on U.S. competitiveness and because data were available. While important lessons can be learned from these industries, the committee recognizes that its analysis may not apply to other manufacturing industries with widely varying cost structures.

2. Lean production is defined and discussed by James P. Womack, Daniel T. Jones, and Daniel Roos in *The Machine That Changed the World* (New York: Rawson Associates), 1990.

1

Introduction

In the past decade, several trends in the U.S. economy have led policymakers and industry leaders alike to question U.S. international industrial competitiveness. Though the relevant issues can be framed in many contexts, an important underlying concern has been the future of the United States as an industrial power. Can competitive manufacturing still be achieved in the United States or is the future one of low-volume, high-value production with diminishing employment opportunities? At first glance this question may be a sensible one. Two trends, in particular, seem to indicate that the United States has become less attractive as a location for mass market products:

- U.S. firms have lost market share in industries they once dominated, such as consumer electronics, semiconductors, and automobiles. The corresponding gains in market share by foreign companies have often been attributed to production cost advantages that cannot be matched in the United States (see Figures 1-1 to 1-3).
- American manufacturers have been steadily locating manufacturing capacity offshore over the past two decades to serve both foreign and domestic markets. Often such moves are made to take advantage of low-cost labor. More recently, however, firms have gone offshore to find skills, technologies, and materials that are either unavailable in the United States or too costly.

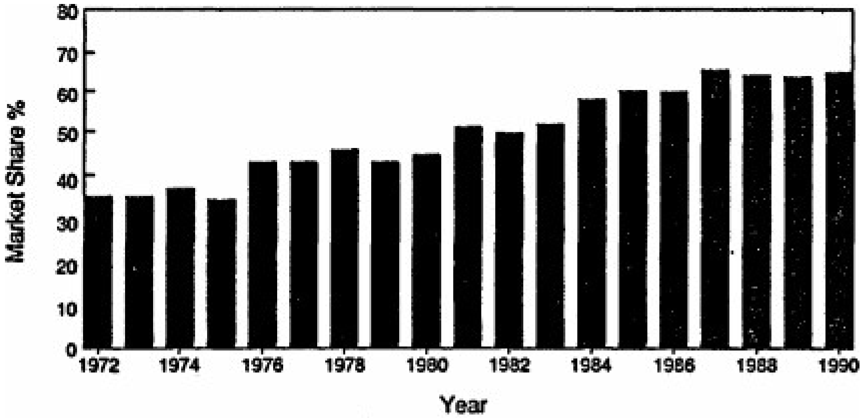


Figure 1-1 Foreign penetration in U.S. market: consumer electronics.
Source: Department of Commerce, U.S. Industrial Outlook 1986, 1988, 1990, and 1991.

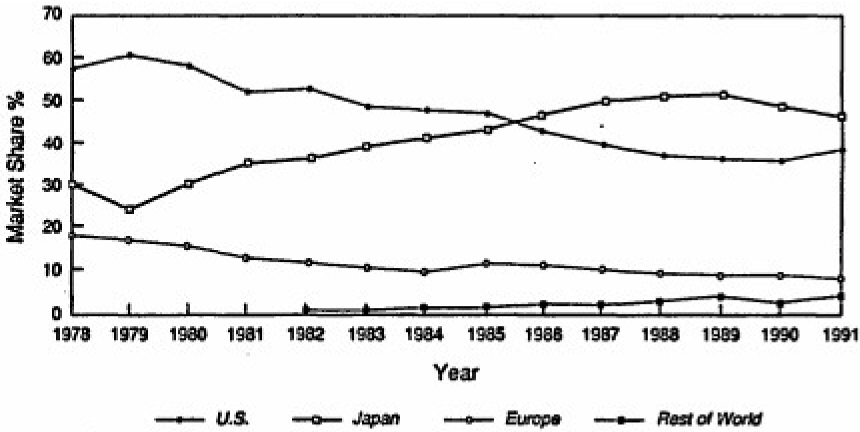


Figure 1-2 World production of semiconductors by region.
Sources: National Advisory Committee on Semiconductors Report 1991 and Dataquest.

The quick conclusion often drawn from these trends is that the United States can no longer host competitive manufacturing: the cost of wages and benefits is too high and U.S. workers are too inflexible (with respect to work rules and production practices) to compete with their foreign counterparts.

Given the disturbing implications of such a conclusion, the Committee on Comparative Cost Factors and Structures in Global

Manufacturing was formed to examine the relationship between manufacturing costs and global factory site selection decisions and to improve the level of understanding of the evolving environment for international manufacturing competition. Changes in technology, the dynamics of international trade and investment, and continued advances in manufacturing efficiency have altered the cost structures faced by manufacturers and the priorities given to various investment criteria. Although all the activities that comprise the product realization process—e-sign, engineering, purchasing, production, marketing, distribution, and sales—determine the full costs of bringing a product to market, manufacturing costs incurred in the factory are typically what affect decisions to shift production offshore. These costs are, therefore, the focus of the committee's analysis.

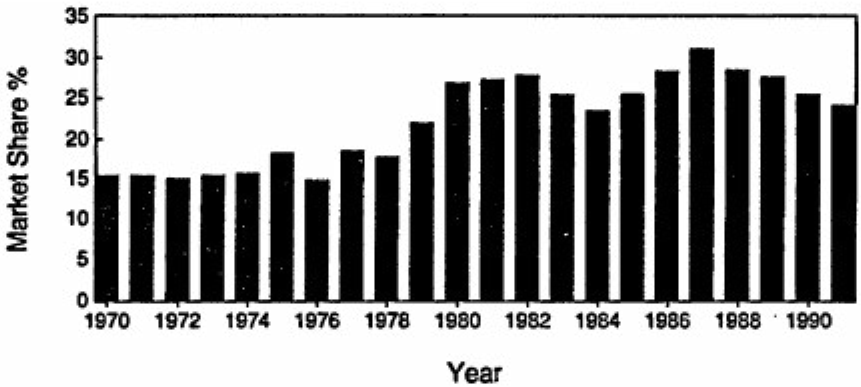


Figure 1-3 Foreign penetration of the U.S. automobile market.
Source: Motor Vehicle Manufacturers Association of the United States, Inc., Economic Indicators Report, 1992, p. 12.

THE STRATEGIC BUSINESS DECISIONS MODEL

Given the complexity of these issues and the multitude of factors affecting factory location decisions, the committee developed a strategic business decisions model (Figure 1-4) as a tool to structure its analysis. The model links site location decisions directly to an overall business goal, broadly defined as maximizing "total business potential." On a continuing basis, firms need to make certain strategic and operational decisions to guarantee their longevity and to maximize their total business potential. Although no model can capture all of the factors involved in such decisions, this simplified model highlights the relevant factors generally considered at any given time and how those factors are weighed in different circumstances.

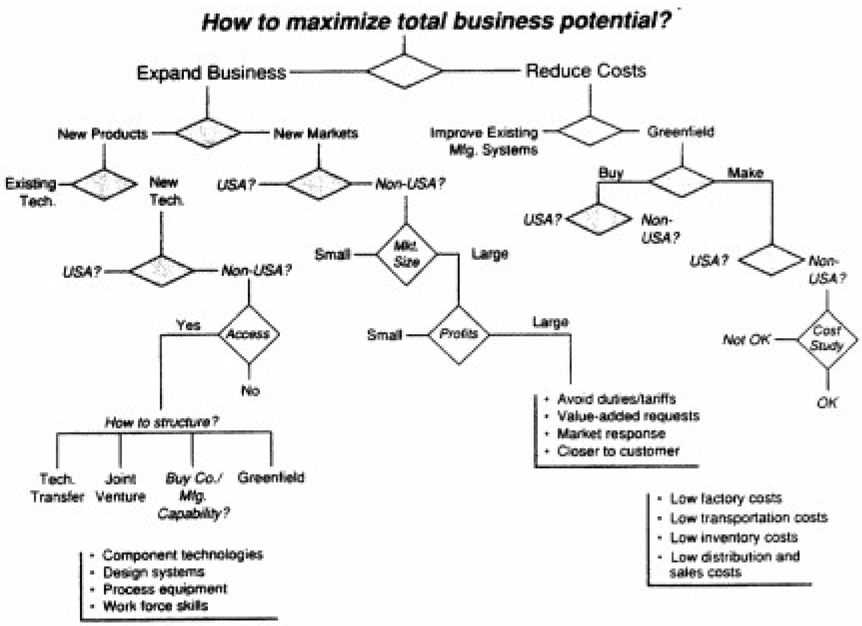


Figure 1-4 Strategic business decisions model.

For the sake of simplicity, the model starts with the premise that firms seeking to maximize total business potential have two strategic options: they can reduce costs (and so, potentially, increase margins) or expand the business. The emphasis placed on each of these strategies often depends on how the firm's production costs compare to competitors' costs. If the firm's costs are too high, it will not have sufficient margins (at the selling price defined by the market) to expand the business or to meet the many requirements (e.g., product features, performance, variety) imposed by competition. However, if production costs are competitive, that is, low enough to maintain strong margins, the firm has the resources and gains the flexibility to compete On a basis other than price. Factors such as product quality, features, and availability become key to competitive strategy; product differentiation and penetration of new markets needed to expand the business become more feasible. Essentially, lowering production costs provides the means to be a stronger participant in dynamic, competitive markets.

Clearly, this is a simplified model. The two strategies are not mutually exclusive. Firms may reduce costs and expand the business simultaneously, effectively adding more value to existing products while creating new products and markets. In fact, it may be necessary to pursue one strategy to achieve the other. A firm may find it needs to expand the business to reduce costs because of minimum scale requirements. For instance, Digital Equipment Corporation has built external sales of magnetic heads for disk drives because its internal requirements were insufficient to justify the cost of plant and equipment. On the other hand, a firm may find that market pressure to reduce costs leads to greater use of outside suppliers who have lower production costs, resulting in diminished in-house production. For these reasons, these strategic options should not be seen as an either-or approach to maximizing business potential. Firms use a combination of the strategies articulated in the model, often with synergistic effects.

It should also be emphasized that a firm's strategy for maximizing total business potential is affected by a large number of variables not reflected in the model. For instance, firms must realize certain margins in order to keep investing in new products, facilities, skills, technologies, and equipment. Margins are determined in part by how low a firm can drive costs, but also by the price that the manufacturer can command for a product. Producers who can realize higher prices for their products may reap the same profits that other producers might achieve by lowering costs. Prices are driven up or down by a wide variety of forces. Downward pressure on price, for example, can be the consequence of an increase in the number of competitors, the introduction of cost-saving manufacturing processes, or a competitor's access to lower-cost inputs (the latter two allowing a producer to lower prices while still achieving acceptable margins). Access to technologies, skills, and processes can help a firm shift its supply curve (effectively allowing it to produce the same product at a lower cost or to produce more of the same product at the current cost). On the other hand, the acceptable price of a particular product can be driven up because of its quality, brand, features, or uniqueness. Improvements in these product attributes will affect demand consumers will be willing to pay a higher price if they perceive a product to be of high quality, if it is available, or if it meets their unique needs.

Firms that can simultaneously drive down production costs (supply enhancements) while adding value for which customers will pay more (demand enhancements) can radically change the terms of competition in a given market. For example, the arrival of low-cost Japanese automobiles in U.S. markets during the 1970s and 1980s and the subsequent Japanese success in a variety of market segments forced many U.S. manufacturers to pay attention not just to cost (in which the Japanese were more competitive) but also to quality and features (in which the Japanese were also more competitive). The entrance of new competitors who had different cost structures and a different manufacturing philosophy changed—for the entire industry—both the acceptable price an automobile could command and the levels Of quality, features, and availability customers would expect. Similar changes have taken place during the same period in consumer electronics and, more recently, in the semiconductor industry.

Despite its simplicity, the strategic business decisions model provides a useful tool for analysis of the factors affecting factory location decisions. Because of the charge to the committee to examine the effects of costs on site selection, the analysis focuses on the decision chain that emerges under “reduce costs,” rather than decisions needed to "expand business." One way to reduce costs is to reduce expenses—the costs of doing business that are not directly associated with production. Examples include marketing, legal expenses, communication systems, insurance, and other overhead functions. Though critical in the overall cost structure of the firm, they do not typically change very much with changes in production location and therefore have not been a focus for the committee.

More germane to the committee's analysis is reduction in the manufacturing cost of goods sold (COGS).[1] How managers address this objective is profoundly affected by their understanding of what drives production costs. Traditional mass producers tend to define production costs narrowly—managers focus on minimizing input costs defined in narrow accounting terms. Because standard accounting practices allocate indirect costs on the basis of labor content, labor costs tend to be greatly exaggerated as a component of COGS. Consequently, in practice, minimizing input costs has meant minimizing labor costs. The result is that investment decisions have often been put in the context of investing in automation to reduce labor content or moving production offshore to reduce labor costs.

TARGET COSTING

There are several ways in which a firm can calculate the acceptable cost of manufacturing. Some firms look at costs as a given, which, when subtracted from revenue, will indicate margins. Business strategy then focuses on what is done with the resultant margins. There is another way to deal with costs, however. Target costing, a technique developed by Japanese manufacturers, starts with margins. A firm builds a business strategy on the basis of the margins it will need if it is to make key investments and remain competitive. After deciding what future investment needs will be (in the context of a strategic business plan), a firm looks at the potential product revenue. By subtracting the needed margin from revenue, a firm calculates a "target cost," the cost it must achieve if it is to remain competitive, In this way the business strategy, not the cost structure of production, drives a company to set production goals and product prices in a proactive way.

Historically, automation has been applied most readily to tasks in which the size, accuracy, or hazardous nature of the operation preclude manual labor—automobile painting, for instance—or to tasks that are so repetitive that boredom affects quality. Broader applications were limited because the flexibility required for effective production was beyond the capability of the technology. Consequently, many assembly operations, particularly those using a variety of small parts such as electronics, could be done only by humans. In these cases in which direct labor remains a major cost factor, offshore production continues to be an attractive, and sometimes essential, option.

Two developments over the past 10 to 15 years have changed the historical role of automation. First, advances in manufacturing process technology, engineering design, and computer control have rapidly expanded the capabilities and applicability of automation. Products are designed with fewer parts, so they require less assembly; advanced sensors and precision control allow automation of a wider range of manufacturing operations; and increased process flexibility has diminished, though by no means eliminated, the cost and risk of automating the production of products with shorter and shorter market lives. Whether to automate and determining the appropriate level of technology to use remain difficult decisions—factors to consider include the cost of the equipment versus its benefits in terms of improved safety, precision, quality, yields, and volume of production, as well as potential labor cost savings—but the rapid pace of technological progress has certainly made automated production a viable option in an increasing number of cases.

Second, increased understanding of the interrelationships throughout the manufacturing system has resulted in greater productivity, tighter control of processes, and a more effective combination of humans and machines on the factory floor. Spurred by Japanese competition, a growing number of firms are treating manufacturing as an integrated system and using new management techniques such as just-in-time inventory systems, total quality management, and concurrent engineering. Their understanding of the drivers of COGS expands dramatically, multiple opportunities to improve existing facilities are recognized —in fact, continuous improvement of the existing manufacturing system becomes the driving force of the total enterprise—and site location decisions for greenfield factories are based on many criteria besides input costs.

Firms taking such a broad view of manufacturing recognize the costs associated with poor design, an inflexible development cycle, or a poorly managed production floor. When these firms seek to reduce COGS, they first look at the effectiveness of their design, engineering, and manufacturing processes in existing facilities for sources of improvement. Decisions to expand or change the location of capacity are based on assessments of the degree of improvement possible and how long it would take to achieve. The decision to establish new production facilities may be intended to accelerate the pace of change as well as to expand capacity. When considering prospective manufacturing locations, they are not looking simply for low-cost production labor, engineers, or materials. They are looking for an environment that will allow them to address all of the drivers of cost—one that allows them to manage an enterprise to maximize product value with the most efficient use of resources.

In today's global manufacturing environment, treating manufacturing as an integrated system and applying the full combination of techniques, methodologies, and technologies provides distinct advantages in meeting consumer/market demands. Indeed, the high quality, low-cost, and responsiveness associated with advanced manufacturing practices have actually reshaped the demands and expectations of the market. When traditional mass producers try to compete simply by further compartmentalizing the manufacturing process and maximizing volume, they are responding to new challenges with old tactics. In this situation the traditional mass producer is more likely to make a poor site location decision that translates into noncompetitiveness.

REPORT STRUCTURE

With the strategic business decisions model providing context, along with the committee's understanding of advances in manufacturing process technologies and manufacturing as an integrated system, the committee examined three industries— consumer electronics, semiconductors, and automobiles—to elucidate trends in production costs and patterns of foreign investment. These three industries were chosen, first, because data were available (though to varying degrees) and, second, because each represents a different experience in offshore manufacturing. Consumer electronics was one of the first and more extensive practitioners of moving abroad to cut labor costs.

Semiconductors has moved offshore for packaging but otherwise has dispersed to developed countries for market access. Finally, automobiles has, in fact, experienced relatively little movement of production; the major incidence is Japanese producers coming to North America and Europe for market access.

The industry studies focus on large corporations because, with their resources and knowledge, they have more options than small firms have regarding where they perform production. Issues of global manufacturing, in fact, may look much different to the small manufacturer. Given the extremely diverse characteristics of small manufacturers, generalizations are inappropriate, but several conditions of the small firm's competitive environment are common enough to note. First, they often are vitally connected directly or indirectly to larger firms as suppliers. Their prosperity, even survival, depends on their ability to adapt to an environment that is constantly being shaped by their larger customers. Second, small firms often do not have the same options as a large firm to adjust to global competition. In many cases their processes are more labor-intensive because they lack the resources to automate and their products may be too diverse to make affordable automation viable. Small firms producing parts and subassemblies, therefore, may be significantly more vulnerable to foreign competitors with low-cost labor, particularly if their large-firm customers base their buys on price. In the context of small firms, "moving offshore" often means losing business to foreign suppliers.

On the other hand, small firms face the same issues as large corporations in managing their manufacturing operations for high-quality, responsive, cost-effective output. As suppliers they often have an intrinsic advantage in their proximity to their customers that foreign competitors cannot match. To the extent that moving offshore is less of an option for small firms, the incentive to get their processes in control and to maximize value to their customers should be all the more apparent. In this context the committee's findings regarding what is necessary for competitive production in the United States applies equally to small and large firms.

The three industry analyses are intended to chart how certain factors have influenced site location decisions in industries where costs, markets, management strategies, and manufacturing processes are changing. To the extent data are available, manufacturing costs in each industry are disaggregated into different components and then linked to site location decisions and manufacturing competitiveness. In particular, the committee has tried to demonstrate how new approaches to driving down costs have significantly changed the criteria that companies use to decide on manufacturing locations.

Chapter 5 of this report describes what the committee has learned from its examination of the three industries. Chapter 5 also dispels a number of misconceptions about the strategic role of overseas production, summarizes the attributes that are drawing manufacturers to certain locations, and explains the reasons those attributes are attractive under various conditions. From these observations the committee offers several conclusions about the attractiveness of the United States as a future location for different kinds of competitive manufacturing. Recommendations for appropriate government and industry action also are made.

There is a danger in this kind of analysis of letting the assumptions drive the conclusions. The committee's starting point was and is cost, but it is clear that cost is not the sole or even the determining factor in site location decisions or competitiveness. It must be understood that cost data used in the industry analyses serve as a point of departure. Perhaps one of the most important insights that can be drawn from the committee's work is that the more cost data are scrutinized, the clearer it becomes that a strict cost analysis cannot capture all the variables that determine where firms manufacture or how competitively they manufacture. This experience reveals the dangers of taking a limited view of costs or of letting cost analyses drive strategic business decisions.

NOTE

1. COGS reflects a variety of direct and indirect costs required to bring a product to market. It includes direct factory costs (e.g., labor, load, materials, and scrap); transportation costs; duties; and indirect costs and expenses (e.g., depreciation, R&D, and administration).

2

Consumer Electronics

It is commonly believed that U.S. manufacturers cannot compete with offshore manufacturers because the United States is a "high-cost" manufacturing environment, particularly with respect to direct labor. An examination of the consumer electronics industry, however, demonstrates that this high-cost labor scenario is not really descriptive of the realities faced by manufacturers in this industry.

The committee has used an analysis of two products to demonstrate when labor costs can and cannot be a decisive factor in site location decisions by consumer electronics manufacturers. The analysis focuses on two products: an AT&T telephone and a Toshiba color picture tube. Both products are manufactured in the United States and abroad. Each company chose to locate facilities abroad for different reasons: AT&T sought rapid cost reductions achievable from lower labor costs abroad, and Toshiba sought greater market access security.

The committee's analysis of the manufacturing costs of these two products revealed how complex site selection can be. Although AT&T shifted production of business telephones to Singapore in 1984, at a time when direct labor accounted for 22 percent of the cost of goods. sold (COGS) in its U.S. factory, productivity improvements over time have changed the relative benefits of offshore labor. In fact, AT&T's 1990 study shows that differentials in the cost of materials, not direct labor, now provide the offshore cost advantage.

Further, the committee has found that direct labor costs and, for that matter, total production costs are not necessarily higher in the United States than they are abroad. The Toshiba analysis demonstrates that the manufacturing cost for a color picture tube is actually lower in the United States than in Japan (a function of exchange rate differentials). Clearly, the assumption that U.S. manufacturers are at an insurmountable disadvantage because they work in a high-cost labor environment does not square with the experience of these two manufacturers.

THE AT&T EXPERIENCE

Background

In the wake of the Federal Communication Commission's deregulation of domestic telecommunications equipment on January 1, 1983, AT&T was forced to make the transition from a partly regulated to a fully competitive environment. Before the breakup, AT&T leased telephones to its customers, so its ultimate objective was to achieve the lowest overall life-cycle costs, leading customers to associate reliability with all telephones. With the breakup of AT&T, however, consumers began buying their own telephones and foreign manufacturers began to flood the marketplace with inexpensive and, in many cases, poor-quality equipment. AT&T lost market share to these new producers, some of which it regained when customers found many of the low-cost new telephones lacking in quality.

To become more competitive, AT&T had to control its production costs. This would be difficult, however, since the mindset in both the factory and the corporation was still shaped by reliability considerations. Responsiveness was undervalued. This mindset produced high prices, falling revenues, and low profitability.

In response to these problems, AT&T implemented a restructuring plan, "Project Turnaround," to reevaluate its product line and control costs. The objectives of the project were to:

- absorb a cost structure established for a very different business
- revise a revenue stream in decline (a leased base of telephone equipment)
- overcome unacceptable profitability projections
- merge cultures from many former Bell System organizations

Ultimately, AT&T needed to make its consumer products business profitable if it was to survive in the new environment. Yet these products were, in many instances, not competitive with the rest of the industry. For products manufactured in the United States, the COGS was 75 to 95 percent of net revenue. The industry analog, however, was 60 to 65 percent. Further, it was unlikely that the onshore labor cost disadvantage could be rapidly overcome by cost improvement programs. Labor cost advantages offshore were simply too great.

To meet the challenge of manufacturing a new line of residential products quickly, at sufficient quality and price to yield good margins, AT&T turned to offshore manufacturing. Existing residential products were phased out of U.S. factories and a new line of products was manufactured offshore, either in AT&T-owned facilities in Singapore or by suppliers called original equipment manufacturers[1] (OEMs), typically in Korea, Hong Kong, or Taiwan. Effectively, this decision was taken because the immediate benefits of moving offshore outweighed the cost and difficulty involved in bringing its domestic factories up to world-class standards.

The decision either to outsource or to manufacture abroad was made on the basis of certain attributes of foreign manufacturing environments that AT&T found attractive. The attributes or "attractors" that initially brought AT&T to foreign manufacturing locations were:

- access to low manufacturing costs: materials, labor rates, duties (Generalized System of Preferences status), taxes, transportation
- access to skills (engineers, technicians, managers who had not been "tainted" by outdated management styles)
- access to OEMs that made products AT&T found too costly to build in the United States

In the wake of AT&T's restructuring, several of its manufacturing operations are now located offshore. This global manufacturing network now includes capacity in Singapore, Taiwan, Thailand, Hong Kong, other Asian countries, and Mexico. Further, after benchmarking domestic operations against foreign ones, AT&T has improved its domestic manufacturing capabilities. Improved onshore manufacturing, in turn, is altering the criteria by which AT&T makes site location decisions—making onshore manufacturing more attractive in all performance categories, including cost.

AT&T Product Cost Analysis

In 1990, six years after the consumer products' turnaround plan was implemented, AT&T reexamined comparative manufacturing costs between domestic production and offshore OEM production in a range of consumer product lines. This new analysis was undertaken to:

- identify and understand full-stream costs
- identify and understand the sensitivity of the key drivers of cost
- quantify hidden cost elements
- develop a benchmark for onshore manufacturing
- refine existing make/buy analyses

This analysis disaggregated the COGS into four categories, specifying the cost advantage for that component if the items were to be manufactured offshore (Table 2-1). After estimating the total onshore/offshore cost differentials when landed in the United States, the offshore cost advantage was found to be 8 percent. To find ways of reducing that differential, cost components and drivers were analyzed in further detail.

Labor Analysis

While it is clear that dramatic differences in wage rates across countries (see Figure 2-1) make foreign manufacturing locations attractive for labor-intense operations, AT&T's study showed that in-plant direct labor, in fact, accounts for a small proportion of production costs for the products examined. Even with a wage differential as high as 85 percent, the low percentage of labor costs in COGS (9 percent) means that eliminating that differential reduces total loaded costs by only 4 to 10 percent. How important that differential is in a cost reduction strategy depends on the product and the opportunities to reduce costs in other areas.

TABLE 2-1AT&T's Analysis of Onshore/Offshore Manufacturing Cost Differentials

	Component of COGS (%)		
	Typical Domestic	OEM	Offshore Cost Advantage (%) (Disadvantage)
Labor	9	4-10	40-85
Load (includes overhead salaries, benefit costs, taxes, and building/ equipment depreciation and maintenance)	14	3-13	40-80
Materials	70	50-80	12-20[a]
Functional Drivers Adding to OEM Costs (includes transportation, duties, OEM administration, quality management, purchasing operations, R&D costs, fixed central expenses, tooling depreciation, make-to-order)	N.A.	26-41	(24-40)

[a] When consigned parts—parts supplied to the OEM by AT&T—are included. For other than consigned parts, the offshore cost advantage ranged from 13 to 28 percent.

For some products in some markets, a potential 10 percent cost savings can mean the difference in being competitive. In general, AT&T's more labor-intensive products, which tend to be fairly unsophisticated technologically, are more likely to benefit from offshore production. Low-technology products that are hand assembled cannot be competitively manufactured in the United States. Though an analysis must be performed on every case, AT&T has found that a product with a fully loaded manufacturing cost of about $50 is likely to be produced more cost competitively offshore; as onshore production continues to improve, that threshold will fall lower.

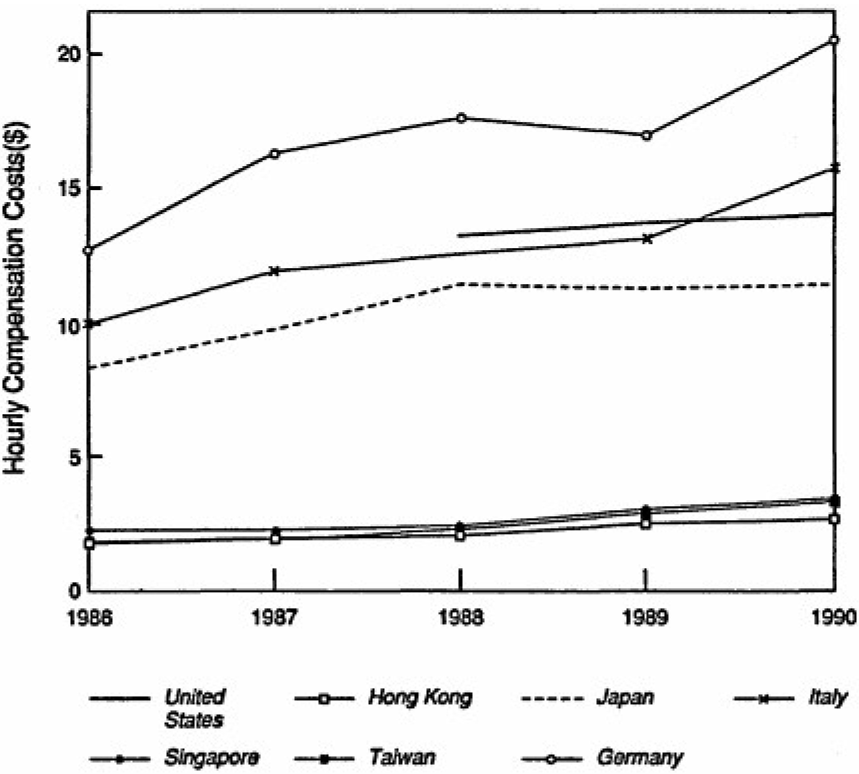


Figure 2-1 Hourly compensation costs for electric/electronic equipment (SIC 36).
Source: U.S. Bureau of Labor Statistics, 1991.

Load Analysis

AT&T found that load is a major driver of the cost differential between onshore and offshore manufacturing because load rates are much lower abroad and load is a significant portion of COGS (14 percent). Typically, about half of load costs are incurred in fixed building-related costs, equipment depreciation, salaries for indirect labor, and other direct costs. Consequently, as equipment requirements increase with higher-technology products, load becomes a higher proportion of total costs and the onshore/offshore differential declines. The offshore producer is faced with the same need to invest in capital equipment for sophisticated product manufacture as AT&T.

For the products examined, load percentages range from 12 to 16 percent for AT&T onshore manufacturing, compared with 3 to 13 percent for offshore suppliers. The wide range for OEMs is due to their specialization in different technologies. OEMs that produce low-technology, manually assembled products require little capital investment and therefore have lower load rates. OEMs that produce higher-technology products tend to have load rates comparable to those of AT&T.

Salaries and wages for indirect labor (engineers, managers, and administrative personnel in the plant), which are another component of load, are a source of some of the onshore/offshore load differential. As Table 2-2 illustrates, foreign engineers and managers are substantially less costly than comparable U.S. personnel. Because engineers are less expensive, foreign managers at AT&T's suppliers' plants typically use more of them in manufacturing operations that must achieve high yields quickly. AT&T has found that foreign engineers are as competent as their U.S. counterparts and are often assigned in large numbers to manufacturing process improvement (an assignment that is frequently undervalued in U.S. factories). This focus on yield improvement, in turn, reduces production costs as yields increase.[2]

AT&T's onshore plants have historically reduced their own loads by about 5 percent each year through the more efficient information and engineering systems that have been installed to enhance white-collar productivity. Similarly, it is assumed that offshore OEMs make the same kinds of improvements and so will continue to maintain appreciably lower load costs.

TABLE 2-2Average Salary of Key Positions (U.S. dollars)

	“Greenfield”	Mexico	Malaysia
Senior engineer	$52,500	$13,300	$28,100
Engineer	40,000	11,400	17,160
Production supervisor	28,000	7,100	14,900
Secretary	18,500	5,200	6,600

SOURCE: AT&T (1989).

Materials Analysis

Because labor cost differentials tend to dominate discussions of onshore/offshore manufacturing costs, the actual cost impacts of the materials used to build products are often both underestimated and misunderstood. A cost analysis reveals that, at least with respect to this product, materials are the largest proportion of COGS (70 percent). Although the onshore/offshore materials cost differential is smaller than that of other components (it is less than a third of the differential for labor or load), a relatively small change in the cost of materials can significantly cut total manufacturing costs.

The AT&T cost study found that because AT&T is not a local manufacturer in certain areas, it buys materials at a disadvantage. Even when AT&T operates offshore plants in close proximity to OEMs, there is still a substantial price differential—ranging from 6 to 8 percent—between prices quoted to AT&T and those gained by local manufacturers.[3] Considering the large share that materials represent in the total manufacturing cost of telephones, a 10 percent reduction in the cost of materials is equivalent to a 35 to 40 percent reduction in labor and load costs. Looked at another way, reducing the cost of materials by 10 percent at an onshore production facility would trim 7 percent from the fully loaded manufacturing cost. A 7 percent decrease in manufacturing costs, in turn, is often enough to make higher-technology products made in the United States cost competitive with those produced offshore.

This cost differential in materials is in part a consequence of U.S. withdrawal from the consumer electronics industry. For AT&T's product set, abandonment of the consumer electronics industry in the United States is now having a ripple effect that goes beyond that specific industry. Many of the components and subsystems that are used to manufacture the products that AT&T studied are available only from Far Eastern suppliers. Faced with a lack of domestic suppliers, AT&T and similar companies have no choice but to buy foreign materials.

Offshore OEMs achieve their advantage in materials costs in the Far East in several ways. Relying on close relationships with local suppliers, offshore manufacturers are regularly able to use techniques such as spot buying to take advantage of temporary overstocks or bargains. More importantly, despite their integration into a highly internationalized manufacturing environment, they retain significant national/cultural links with materials suppliers. These links translate into preferential treatment when local buyers purchase materials from local suppliers. The relationship between buyer and seller has a significant impact on costs. A U.S. manufacturer like AT&T, when it must buy materials abroad for a lack of alternatives, is at a disadvantage (see Figure 2-2).

To keep its onshore, higher-end telephone manufacturing effort cost competitive, AT&T is attempting to make at least a 10 percent reduction in its materials costs by reaching global material purchasing agreements with its offshore suppliers. Instead of buying materials from a Far Eastern supplier's distributor in the United States, AT&T is negotiating bulk purchases at the supplier factory and assuming the cost and logistics of shipping and distributing the items to its own factories. AT&T sees this initiative as a potentially decisive factor in keeping the onshore manufacture of its higher-end telephones competitive. By making the 10 percent cut in the cost of materials,

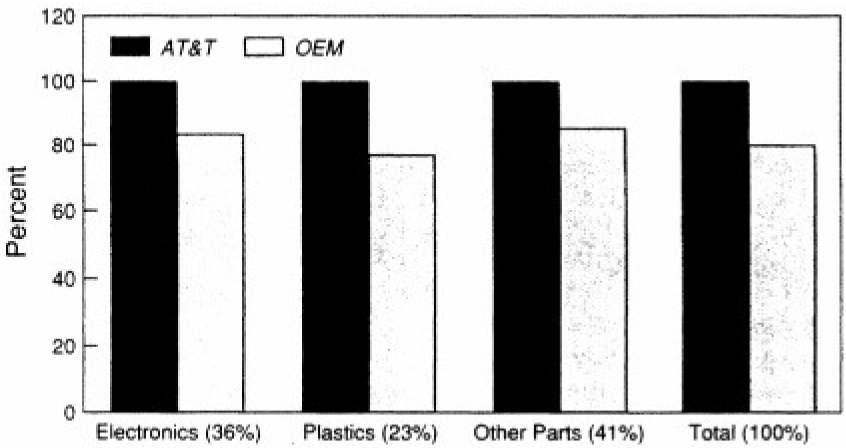


Figure 2-2 Cost of purchased material at AT&T and OEMs for the same materials, often from the same supplier, all offshore.
Source: AT&T.

AT&T expects that it can manufacture more of its telephones onshore competitively (see Figure 2-3).

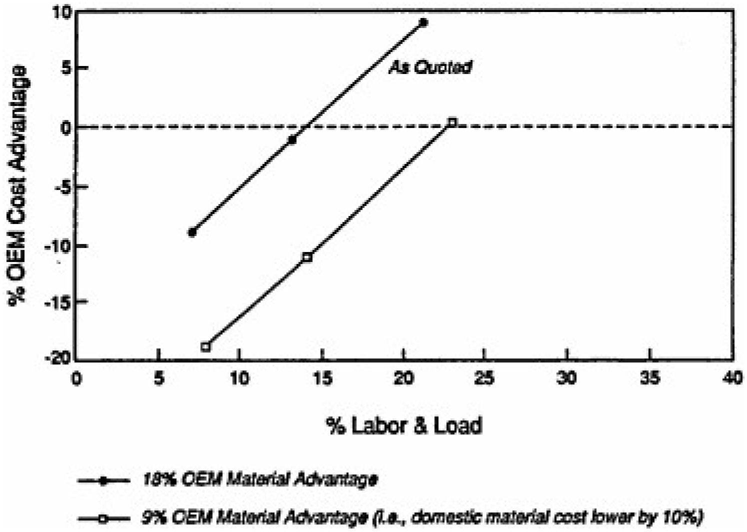


Figure 2-3 Assuming an 84 percent labor/load advantage, labor/load in onshore plants must be under 14 percent to be cost competitive with OEMs with an 18 percent materials cost advantage. By cutting that materials cost differential by 10 percent, onshore production can be competitive when labor/load is up to 23 percent of COGS.
Source: AT&T.

Analysis of Functional Drivers Impacting OEM Costs

Moving production offshore to OEMs incurs costs that need to be quantified and added to an OEM quote when assessing the cost advantage of manufacturing or sourcing abroad. These cost adders include:

- transportation and duties
- qualifying OEMs
- start-up and management costs for OEM vendors
- quality inspection and management
- accounting for central expenses (overhead)
- meeting return-on-investment requirements
- other carrying cost charges

Taken together, these factors add between 26 and 40 percent to the OEM product delivery price quoted AT&T. Several of these cost adders are described below.

Transportation and Duties

Transportation costs are relatively fixed and thus are readily identified, but associated duties can vary and have a major impact on loaded costs. Together, they are the largest functional driver, adding 7 to 10 percent to the OEM quote. The key factor driving this expense is the ability to avoid or lessen duties by manufacturing or sourcing products from countries that meet the General System of Preferences (GSP) requirements.

GSP status exempts or reduces the duty on specific products (based on their level of export to the United States) from developing countries that are trying to increase exports. An important consideration is the fact that this major cost factor is a variable one; a country with GSP status one year can lose it the next as a result of unforeseen political or economic changes. A case in point is Singapore, which supplied AT&T with corded and cordless phones under reduced duties until 1990,

Workers assemble cordless telephones at AT&T's plant in Singapore.
Source: AT&T

when the United States revoked its GSP status. There is now an 8.5 percent duty levied on their manufactured cost—a sizeable penalty.

When manufacturing can easily be moved to another country with GSP status, variability in this cost driver is not so detrimental as to preclude offshore manufacture. Low-technology, labor-intensive assembly and manufacturing operations lend themselves to this type of "shuffle" much more easily than high-technology factories that have expensive, not easily transferable skills and equipment.

Quality Management

Ten years ago the cost of quality management in an offshore operation would not have been routinely considered in a decision to move manufacturing overseas. For most American corporations, quality was not a critical issue as long as failure rates were kept to a reasonable level (say one percent).

In a more competitive environment such as the one faced by AT&T today, products of an inferior quality are not tolerated. As other countries have become world-class competitors, offering quality products at reasonable prices, consumer expectations are now higher than they might have been 10 years ago. When purchasing an electronic product such as a telephone, the consumer has more choices because there are more competitors. Manufacturers literally cannot afford to produce low-quality goods that might push consumers to other products.

In a total systems context, quality is free. Whatever upstream costs are incurred in quality improvement are more than offset by lower rework costs, less wasted materials, higher efficiency of work flow, fewer returns, and fewer dissatisfied customers. There are, however, certain up-front costs associated with ensuring quality in an offshore operation.

AT&T's study found that the cost of quality management for an OEM operation added 1.9 to 6.2 percent to the quoted product price. The added costs come from several sources. First, start-up activities to qualify an OEM include comprehensive audits of vendor manufacturing and management systems, along with initial inspection of vendor output until full-stream production is achieved. Vendor qualification, lot-by-lot inspections, and process improvement also are standard expenses. (These costs are incurred onshore as well and are part of the reason AT&T's onshore load costs are higher.) There is also the need to intensify quality management efforts as a product becomes more sophisticated, when there are quality failures (reinspection/requalification), or as quality standards become more rigorous.

Make to Order

Responsiveness to customer demand is one of the key advantages companies can use to succeed in a highly competitive global environment. Onshore manufacturing is attractive in this respect because, even when an OEM is quickly able to build to a customer's specific order, ocean transport is an unavoidable delay. Because availability is a major issue in a consumer market, firms facing potential bottlenecks in the pipeline from their offshore suppliers must carry additional inventories. The cost of carrying such inventories must be figured into the total cost of offshore sourcing when a firm competes in a make-to-order environment.

Because practically all of AT&T's parts and components suppliers are located in the Far East, AT&T has had to develop a direct pipeline from Asian supplier factories to its domestic plants. The relatively small size and weight of electronic components make them air freightable, and, with well-coordinated trucking and ordering systems, AT&T is able to achieve a six-day turnaround (from order to delivery) on Asian parts destined for its onshore manufacturing plants. When products are made to order onshore with Asian components, additional inventory carrying charges are avoided. If the end product is made in Asia, however, an average of 4 percent additional inventory carrying cost is incurred.

Unquantified Risks

AT&T also studied risk factors incurred in doing business with an offshore OEM, including environmental exposure and the inadvertent transfer of strategic information to suppliers, and concluded that while such factors needed to be considered they were not major cost drivers. One exception, however, is the possibility that lags in OEM production may adversely affect product realization targets.

AT&T's product realization strategy focuses on time to market—that is, the time it takes for a product to move from conception to general availability. This factor, while difficult to quantify, is vital to AT&T's competitiveness and so is included in its analysis of the potential costs of locating offshore.

AT&T's experience with its onshore plants and OEMs indicates that site impact on time to market is a real concern, even though it is difficult to assign a direct dollar value to it. In a study that tracked both company-owned and OEM facilities producing nearly 60 products between them during 1986-1988, AT&T facilities met target production deadlines nearly twice as frequently as OEMs. Factors contributing to the OEMs' poor track record included continued AT&T technical changes during product ramp-up, OEM component supplier problems, and cultural and language barriers.

Managing time to market involves considering the potential risks (i.e., costs) of time delays on product development, manufacture, and delivery. The risks tend to be low with proven technologies and proven suppliers. The risk increases, however, when AT&T must deal with new designs and new suppliers. The relative risk of delay for various attributes of product and producer is illustrated in Figure 2-4.

Summary Observations: AT&T Cost Analysis

The AT&T study of COGS comparing onshore and offshore production prompts the following observations:

- Although offshore manufacturing has inherent cost advantages, their relative importance has changed over time. The factor with the greatest leverage on total COGS—materials—is also the factor with the least offshore advantage.
- It is most difficult to overcome offshore cost advantages for low-technology, labor-intensive products. Included are products that will remain above cost parity even after onshore cost initiatives like global component purchasing are implemented—potentially any product that costs less than $50 for fully loaded manufacture.

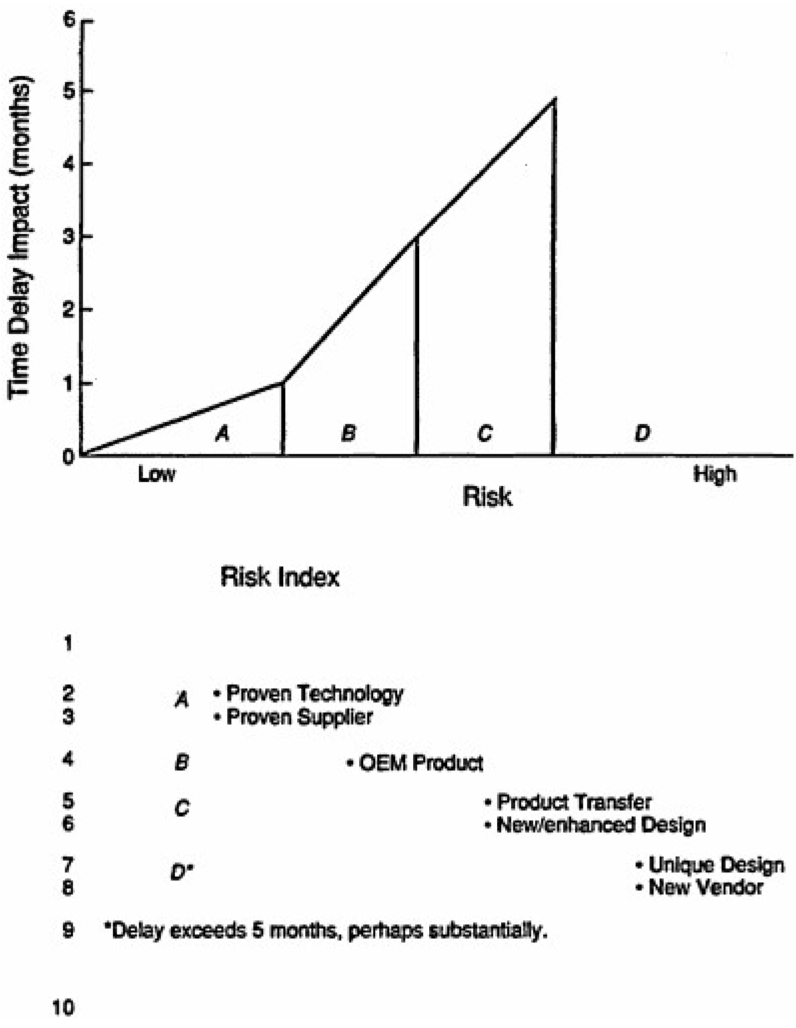
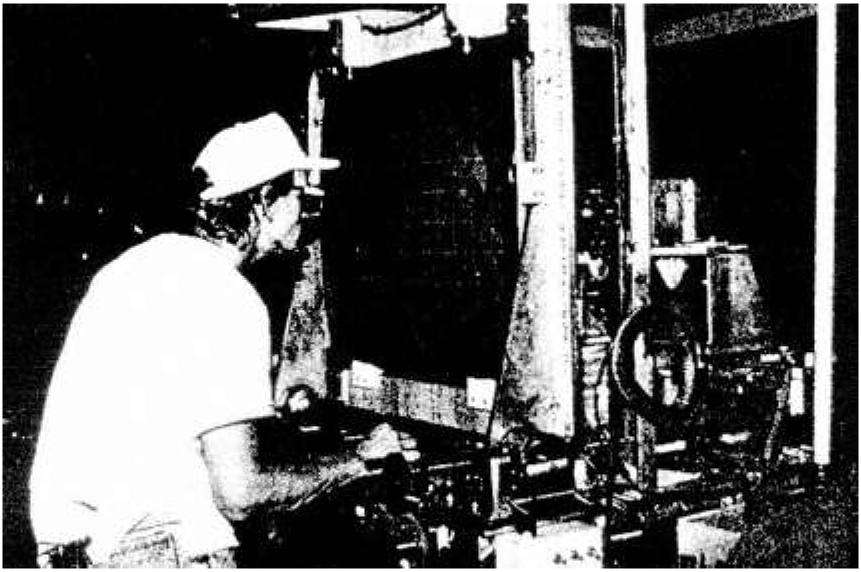


Figure 2-4 Time-to-market impact, relative risk in meeting commitments.
Source: AT&T.

- Material cost reduction programs are key to reducing COGS. Although AT&T's study concentrated on telephones, the same principle holds for many other electronic products.
- Cost adders for offshore manufacturing can become significant if not actively managed (e.g., quality).
- Onshore cost reduction programs need to be aggressively pursued with specific targets if domestic operations are to

approach parity with offshore operations. Highlighted AT&T programs include global component purchasing and continuous load reduction.



Worker inspects color picture tube at Toshiba Display Devices.
Source: Toshiba.

- Factory value-added initiatives such as make to order can provide a differential competitive advantage in comparison with competitors and offshore manufacturing.
- Effectively benchmarking onshore operations against offshore analogs is a means of assessing where improvements could be made in onshore operations. Further, it delineates the limits of improvement and spurs managers to think about alternative ways to lower costs and be competitive.

THE TOSHIBA EXPERIENCE[4]

Background

Toshiba began building color picture tubes (CPTs) in New York in a joint venture with Westinghouse in 1985. Toshiba Display Devices (TDD) employs 1280 people in its New York operation, 850 of whom are direct laborers. Two years after the venture began production, Westinghouse sold its part of the venture because the market for CPTs was not growing as quickly as initially expected. TDD is now a wholly owned subsidiary of Toshiba.

A first-order consideration for Toshiba when it was approached by Westinghouse was market access. After a petition was filed against Japanese television makers by the Electronics Industry Association in 1971, Japanese firms such as Toshiba began to establish television assembly plants in the United States. The demand in the United States for televisions is approximately 20 million sets per year, despite the fact that 98 percent of all households have at least one set. Demand is expected to grow by approximately 1 to 2 percent per year.

Cost of Materials

Regardless of manufacturing location, the most significant cost component in CPT production is materials. Table 2-3 illustrates the major costs, comparing Toshiba's plant in Himeji, Japan, with one in Thailand in 1990. Of the 70 percent or so of total costs accounted for by materials, about 40 percent is glass.[5] Because glass is both heavy and fragile, it tends to be purchased locally to avoid shipping costs; therefore, the cost of glass is a major determinant of the relative cost of CPT production in different locations.

As a proportion of total costs, Toshiba pays less for glass in the United States than it does in either Thailand or Japan, primarily

TABLE 2-3Thirteen-inch CPT Manufacturing Cost Comparison: Himeji vs. Thailand[a]

	Himeji		Thailand	
Cost of materials	689	(68.9%)	704	(72.8%)
Direct labor	74	(7.4%)	20	(2.0%)
Factory overhead	237	(23.7%)	243	(25.2%)
Total	1,000	(100.0%)	967	(100.0%)

[a] Indexed to 1000.

because of the relative capability of local suppliers. Production yields on the high-quality glass demanded for CPTs vary substantially by supplier, ranging from about 40 to 65 percent. Toshiba's American suppliers, benefiting from both superior process control capabilities and product technology transferred from Toshiba's supplier in Japan, achieve yields at the high end of this range, providing cost advantages to Toshiba's American plant. With this as a major factor, it is worth noting that an estimated 90 percent of TDD's required materials were sourced from U.S. suppliers in 1990, and a plan is in place to raise that to 100 percent within the next few years.

Labor Costs

Although direct labor is far less than 10 percent of CPT production costs, and therefore is not a major driver in location decisions, the rate at which workers learn their jobs and improve productivity has an important impact on how quickly a plant becomes competitive. Figure 2-5 illustrates this learning curve effect in comparing the manufacturing costs of TDD about one year after start-up and of Toshiba's plant in Fukaya, Japan. The figure shows both the U.S. advantage in the cost of

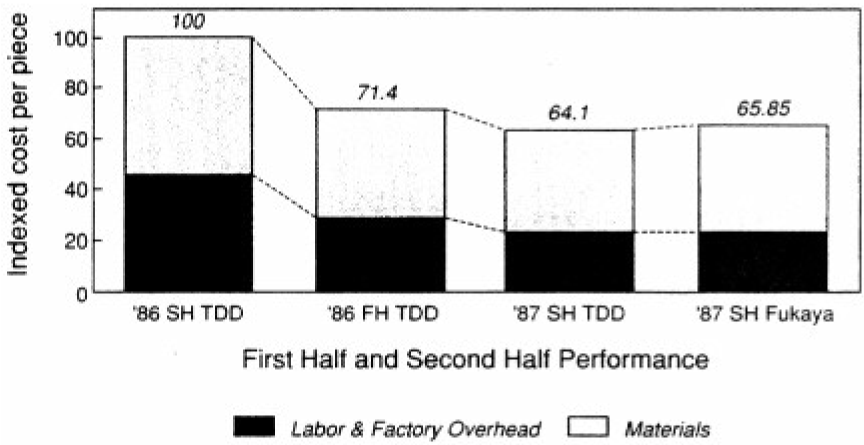


Figure 2-5 Nineteen-inch CPT manufacturing costs, TDD versus Fukaya (Japan).
Source: Toshiba (1986).

materials and the significant drop in labor cost and factory overhead, allowing TDD to undercut Fukaya slightly in overall costs.

TABLE 2-4Comparison of Labor Costs, Toshiba Japan vs. TDD, 1989[a]

	Toshiba Japan	TDD USA
20-inch CPT direct labor (wage and benefits), $/piece	5.80	3.30
Working hour efficiency, hours/1000 pieces	311.96	343.16
Basic wage, $/hour	16.30	7.80
Fringe benefits as percent of wages	14%	23%

[a] The exchange rate used is 125 yen per dollar.

Table 2-4 provides a more detailed look at labor costs in the two locations. The main lesson here is the importance of exchange rates in determining relative labor costs. At the prevailing rate of 125 yen per dollar, American wages are less than half those in Japan; even with higher American benefit rates, labor costs about half ($9.60 vs. $18.60) in the United States. Consequently, despite the 9 percent disadvantage in productivity, total direct labor costs per piece are substantially lower at TDD. By comparison, U.S. and Japanese wage and benefits costs would be equal at an exchange rate of 242 yen per dollar, giving the Japanese plant a slight labor cost advantage on the basis of higher productivity at that rate.

What accounts for this productivity difference? The machinery and equipment for CPT production at TDD is virtually identical to that used by Toshiba in Japan. Yet despite the similarities, a comparison of yield in both plants (Figure 2-6) reveals that TDD achieved yields of 90 percent in the same time it took Toshiba Japan to reach 93 to 95 percent.[6]

The difference in yields can partly be attributed to differences in personnel experience and turnover rates. Almost all of the Toshiba personnel in Japan had approximately 15 years of experience, whereas those in America had none. The training of key TDD personnel was conducted in Japan, which also accounts for the lag in the rate of yield increase. Furthermore, monthly employee turnover at TDD was 4.7 percent in 1987, declining to 2.7 percent in 1988 and 2.3 percent in 1989, but still higher than the Japanese rate of under 2 percent. These factors notwithstanding, however, Toshiba has found that—compared to American and German workers—the yields achieved by Japanese workers are typically higher.

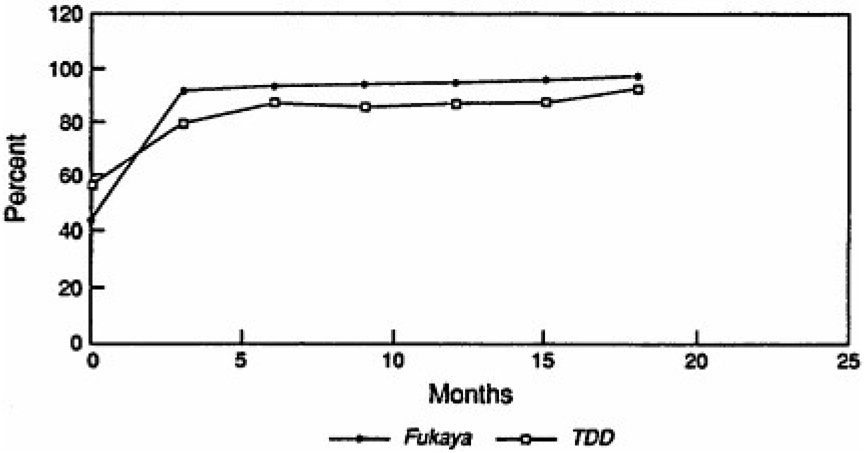


Figure 2-6 Comparison of yield ratio (from start of operation).
Source: Toshiba.

Capital Budgeting

An initial investment of $220 million was required to begin production at TDD. The cost of that initial outlay was de-frayed slightly by low-interest financing offered by the U.S. government and the state of New York.

When automated production was introduced in CPT manufacturing in 1980, continued participation required large equipment investments. In the first five years following the plant's opening, TDD spent approximately $187 million on fixed assets such as machinery, equipment, and facilities. Of that amount, almost $150 million was for manufacturing equipment, $75 million of which was procured from Toshiba Japan.

Toshiba believes that the return on this investment is about

5 percent, significantly lower than the 15 to 20 percent return that U.S. companies often expect on new investments. Toshiba's willingness to accept a 5 percent return reflects its consideration of the strategic value of having significant CPT production in the United States, gaining experience working with U.S. suppliers and an American work force, and having more timely access to technological developments in the United States.

Summary Observations: Toshiba Color Picture Tube Manufacturing

Toshiba's experience manufacturing CPTs in the United States prompts the following observations:

- The primary consideration in Toshiba's decision to locate in the United States was market access.
- Labor is less expensive in the United States than in Japan at recent exchange rates, but it is such a small component of production costs that it has only a small impact on the relative cost competitiveness of Toshiba's plants worldwide.
- Parts and materials are primarily procured in the United States. Extensive cooperation with its U.S. glass suppliers, including transfer from Japan of product technology, coupled with high-quality, high-yield glass supplies, has provided an important materials cost advantage to TDD.
- Despite rapid improvement, the learning curve for TDD was not as steep as a comparable Japanese plant due to higher employee turnover and a less experienced work force.
- Although the initial motivation for Toshiba's investment in American production facilities was to ensure continued market access in the face of protectionist pressures, TDD proved to be a low-cost producer once initial start-up difficulties were overcome. The United States effectively provides a favorable manufacturing environment for this product.

CONCLUSIONS

Of the three major factors in site location consideration—access to markets, access to technologies/capabilities, and access to low-cost—the first was most significant in Toshiba's site selection and the last in AT&T's case. The experiences of AT&T and Toshiba attest to the importance of access to both low-cost and markets, although clearly each firm had different motives and competitive requirements.

AT&T, for example, began manufacturing abroad or outsourcing to foreign OEMs because of cost advantages and the immediate difficulty of raising its onshore facilities to world-class Standards. Finding ways of manufacturing products at low-cost became essential when AT&T made the decision to move offshore in 1984: the market was changing from one that was partly regulated to one that was fully competitive, profitability projections were unacceptable, and AT&T's revenue stream was in decline. Becoming competitive was not a matter of gaining access to the market, but rather of becoming competitive in price while maintaining quality and timely product development.

A different set of circumstances shaped Toshiba's decision to locate a plant in the United States. Unlike AT&T, Toshiba was primarily concerned with market access; its domestic facilities were already working at world-class levels. By manufacturing in the United States, Toshiba could increase the local content of the products it was selling in the United States, thereby assuaging American discontent with the dominance of Japanese imported consumer electronics goods. Further, through a combination of a strengthening yen and capable American suppliers, total manufacturing costs actually have been lower in the United States than in Japan in recent years.

Both these decisions illustrate some of the general principles that affect site decisions within this industry. Among them:

- With respect to low-cost, low-technology consumer electronics products, firms must reduce costs to be competitive. For a manufacturer such as AT&T that produces products requiring materials predominantly available in Asia, the United States is not as attractive a manufacturing location. Instead, these products will likely be produced in areas where labor and materials are comparatively inexpensive.
- When market access is granted on the basis of local content and/or local presence, manufacturing decisions become

very "site sensitive." Because the United States is host to a large and steadily growing market for television sets, it attracts manufacturers like Toshiba who might otherwise be unable to serve this market from a distance.

- External factors such as exchange rate differentials have a major impact on relative production costs in globally scattered facilities.
- Managers in Asian supplier plants place a high priority on yield improvement, often assigning large numbers of engineers to the problem.
- Greenfielding is not simply a method for lowering labor costs onshore. Management is often greenfielded in an attempt to eliminate outdated ways of manufacturing. Similar improvements in manufacturing practice may be expected when moving manufacturing offshore (i.e., changing manufacturing "cultures").
- Managing quality at a distance (in, say, Asian plants) is costly and difficult. Considering the consequences of quality lapses, the potential costs of both ensuring and failing to achieve adequate quality must be weighed in location decisions. Further, Asian or even Japanese manufacturers are not the exclusive practitioners of effective quality management. In some cases, U.S. firms know more about quality production than their offshore OEMs and suppliers. These variations in quality competencies need to be factored into location decisions as well.
- Time to market is often a critical factor in the success of a product. Time to market also impacts production costs. Speeding progress through the product realization process is another way of overcoming onshore/ offshore cost differentials.

NOTES

1. OEMs build products to their customers' specifications for sale under their customers' label.

2. This difference between American and foreign managers regarding process engineering is also reflected in R&D spending. For instance, while American firms spend 80 percent of R&D on products, Japanese firms spend 80 percent on process research.

3. AT&T's wholly owned Singapore manufacturing operation found that they were consistently paying 6 to 8 percent more for materials than local OEMS, even though they were operating under similar conditions. In addition

to local pricing, components suppliers also routinely price regionally—asking as much as each market will bear.

4. Unless otherwise noted, Toshiba data were obtained from Kinichi Kadono, Senior Executive Vice President, Toshiba Corporation, "CPT Production Experience in the United States," presentation to the Committee on Comparative Cost Factors and Structures in Global Manufacturing, April 6, 1990.

5. The precise percentage of materials in total costs varies somewhat by size of tube. For 19-inch CPTs, the range is 53 to 66 percent.

6. Yields calculated as number of nondefective products per number of products inspected.

3

Semiconductors

The lessons learned from the committee's examination of factory site selection in the semiconductor industry are similar to those from the telephone and television analyses. With the exception of high-volume, labor-intense assembly operations, which historically have been located in Asia to minimize labor costs, site selection in the semiconductor industry depends more on factors such as market access and skilled labor availability than on input costs. Although rigorous data on semiconductor production costs were not available to the committee, its discussions with many U.S. semiconductor firms support this conclusion.

The committee's analysis of semiconductors is complicated by the heterogeneity of the industry. Factors that determine production costs vary substantially across device types and technologies. For leading-edge products, such as advanced dynamic random access memories (DRAMs) and microprocessors, manufacturing is capital intense, with R&D and equipment investment requirements rising steadily. Manufacturing competitiveness depends on managing the production process to achieve high-capacity utilization, high yields, and timely market entry and to assure broad market access to achieve high production volumes. For less advanced products, such as microcontrollers, application-specific integrated circuits (ASICs), and analog devices, costs are driven more by packaging and testing because the process technology is older, less advanced, and less expensive. Because of this diversity in the industry, the factors that make specific locations attractive vary widely depending on the specific product and stage of production.

A further complication in trying to understand site selection decisions in the industry is the prevalence of trade barriers. Barriers take a variety of forms but typically are based on local content requirements (prevalent in Europe and many developing countries), minimum prices to counter dumping, and market share constraints/goals.[1] The result is that major producers have fabrication facilities all over the world, new investments are strategically located to ensure access to crucial markets, and increasing interterm collaboration is partially motivated by the need for assured markets and sources of supply.

The combination of these factors means that factory location for advanced products is an integral part of gaining market access to allow sufficient production volumes to amortize high fixed costs from R&D and capital equipment requirements. For low-end products, site selection may be based more on where customers are located to maximize market responsiveness. Almost regardless of the product, packaging tends to be labor-intensive and most is done in Asia.

BACKGROUND

The semiconductor industry represents a significant and growing segment of U.S. manufacturing, as well as a vital link in the global production chain for electronics products. Within the United States, the semiconductor industry is presently one of the fastest growing (in constant dollar shipments) of any four-digit SIC code industry, at 7.9 percent annual growth in 1991.[2] Taken by itself, the world semiconductor market was worth about $54.6 billion in 1991.[3] As the basis for a wide variety of electronics products, semiconductors are strategically linked to a global electronics market worth $750 billion. The semiconductor market is itself, in turn, supported by a semiconductor equipment and materials market worth $20 billion.[4]

Though typically discussed in general terms, the semiconductor market is divided into several distinct product segments. By volume, the largest segment is memory devices, such as dynamic random access memories and static random access memories (SRAMs). This segment has come to be dominated by Japanese producers. Logic devices are the second-largest segment, with American suppliers (mainly Intel and Motorola) dominating the medium and high ends of the business (microprocessors)[5] and Japanese firms leading in the lower end (microcontrollers).[6] ASICs are custom devices; both U.S. and Japanese suppliers have strong positions in this segment.

Concern about the competitiveness of the U.S. semiconductor industry has been driven almost exclusively by losses in the DRAM market, which have been mirrored by Japanese gains (Figure 3-1).[7] The loss of American DRAM production, in turn, has been held responsible for losses in market share in production equipment and materials. As the volume leader and manufacturing process driver (feature density has increased faster in DRAMs and led developments in other product segments), DRAM production demands increases in process equipment accuracy and throughput, as well as material purity. Such realizations have spurred several U.S. manufacturers to take steps to reenter the DRAM market, typically through joint ventures with Japanese producers.[8]

Several explanations for U.S. market share losses have been offered, many of which suggest that the Japanese manufactur

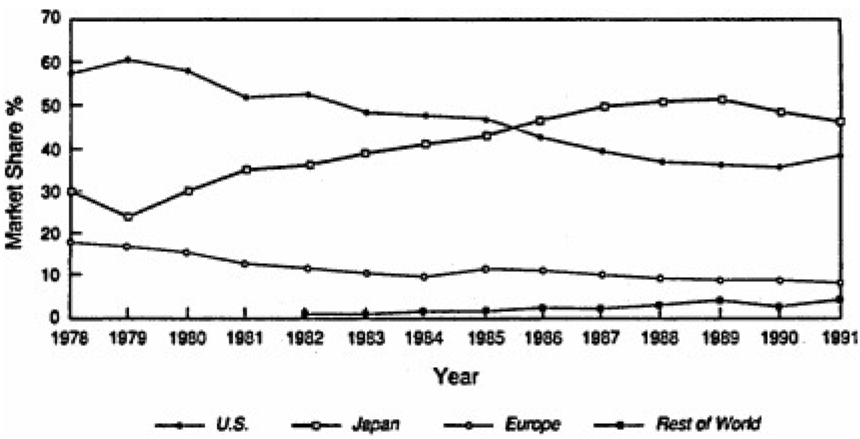


Figure 3-1 World production of semiconductors by region.
Sources: National Advisory Committee on Semiconductors Report 1991 and Dataquest.

ing environment is one that gives Japanese firms unique cost advantages. The premise behind this explanation—that a firm's location helps determine both its costs and, ultimately, its competitive success—is precisely the sort of assumption that this committee was formed to examine.

Industry Structure

Perhaps the primary factor identified as providing Japanese firms with a distinct advantage is the difference in industry structure in the two countries. The Japanese market is an oligopoly in which semiconductor production is dominated by a few large, diversified, vertically integrated firms (e.g., NEC, Fujitsu, Hitachi, Toshiba, Mitsubishi, Sony, and Matsushita). In each of these firms, semiconductor sales account for 10 to 25 percent of total revenues. Nearly one-fourth of the semiconductors produced by each firm are used in its own products. These products range from computers to communications equipment to consumer electronics.[9] Often, these firms hold equity positions in other diversified firms that supply capital equipment, materials, and services. These relationships knit together common interests, the end result being a Japanese semiconductor market that is both highly responsive to product requirements and highly integrated throughout the supply/production chain.

Historically, the American semiconductor industry has had two segments: captive—internal production for internal use, and merchant—production for sale on the open market. This distinction has blurred somewhat in recent years and is expected to diminish significantly through the 1990s. The main captive manufacturers have been IBM, AT&T, and General Motors (Delco). However, fully 50 percent of AT&T's semiconductor production is now sold in the open market, and IBM is projected to be the leading merchant producer by 1995. Although there are a few major exceptions (Intel, Motorola, Texas Instruments), merchant producers tend to be relatively small, relying on semiconductor sales for the majority of their revenues. Many of these firms were founded by individuals who broke from major corporations to start their own operations. Within this segment of the U.S. industry, there are few stable relationships with suppliers. The Supplier base, too, is fragmented.[10]

There has been a large influx of Japanese investment in semiconductor manufacturing in the United States since the U.S.-Japan semiconductor trade agreement in 1986. However, only 21 percent of the employment resulting from that investment came from new investments, with 79 percent of employment coming from acquired plants.[11] Most of this investment has been purchases of U.S. equipment and materials suppliers, though a growing number of fabrication facilities have been established, both to assure market access and to exploit exchange rate differentials.

IMPORTANCE OF PROCESS CONTROL

Semiconductor fabrication is fundamentally capital intensive, though capital requirements vary somewhat by device type, with leading-edge products requiring large and growing investment. For instance, the cost of a new microprocessor fabrication facility (fab) is about $500 million; a 4-megabit DRAM fab costs about $350 million. These estimates are just for the facilities and do not include related preproduction R&D and design costs. Future generations of devices are estimated to cost significantly more. A facility capable of mass producing 64-megabit DRAMs is expected to cost $750 million, in addition to development costs of between $600 million and $1 billion.[12]

Such escalating expenses are driving an increasing number of corporate alliances in the industry designed to share costs, speed development, and broaden market access to assure needed production volumes. Texas Instruments and Hitachi, Motorola and Toshiba, AT&T and NEC, and IBM and Siemens have all announced cooperative agreements to develop the technologies necessary to shrink chip geometries to less than half a micron, required for the next-generations of DRAMs.[13] SEMATECH, an industry consortium including both semiconductor manufacturers and equipment producers and partially funded by the federal government, is another example of cooperation intended to spread R&D costs, share information, and hasten technology development and implementation.

The high capital requirements for DRAM production help to explain the rapid increases in Japanese market share. Throughout the late 1980s the major Japanese producers greatly outspent the top American merchant producers in both R&D and capital equipment investment. In 1989 alone the Japanese spent over $1 billion more in R&D and over $2 billion more in capital equipment.[14]

The reasons for this differential are complex. Some analysts attribute it to lower capital costs in Japan, though there is no consensus on that point. Another factor is industry structure. Because Japanese producers are large, vertically integrated corporations and are part of large *keiretsus*, they tend to be better financed than American merchant producers and have the flexibility to use the profits generated by other businesses to fund semiconductor investment. Faster capital depreciation rates also allow more aggressive investment strategies. For tax purposes, Japanese firms use a three-year accelerated depreciation schedule (54 percent in year one, 30 percent in year two, and 16 percent in year three); in the United States, current depreciation schedules for semiconductor manufacturing equipment permit tax depreciation over five years, although some equipment is depreciated over three to four years for financial reporting.[15]

Given this capital intensity, the determinants of product cost largely flow from changes in manufacturing process parameters, such as capacity utilization, yields, and production volume. Some insight into the relative impact of changes in various manufacturing process parameters on production costs can be gained using computer modeling. A 1989 study done for the Semiconductor Research Corporation modeled the production processes required to make a 256k CMOS SRAM.[16] The model was designed to indicate the required selling price for the chip, given profitability objectives, as parameters in the manufacturing process are changed. Thus, it is useful both in highlighting many of the process variables critical to effective chip production and in illustrating the effects of changes on manufacturing costs.

Figure 3-2 illustrates the results of the model for a number of parameters. The number of chips per wafer has the greatest impact on production costs, though the model assumes chips per wafer to be a function of product design, not changes in wafer size. (Larger wafers hold more chips, but changing wafer size requires changing much of the process equipment.[17]) Production volume also has a large impact on costs, with the model simulating volumes ranging from 24 million to 36 million chips per year. Control of the manufacturing process as reflected in yields also has a significant impact on costs. Several other variables with lesser effects are also illustrated. Though useful in illustrating several cost drivers, the model does not address others, and by focusing on one product it is not truly indicative of the production challenges facing semiconductor manufacturers.

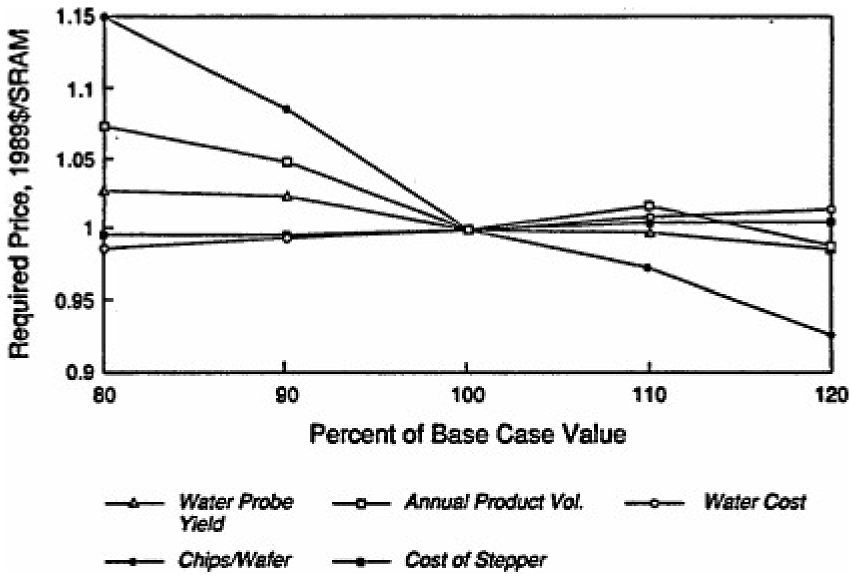
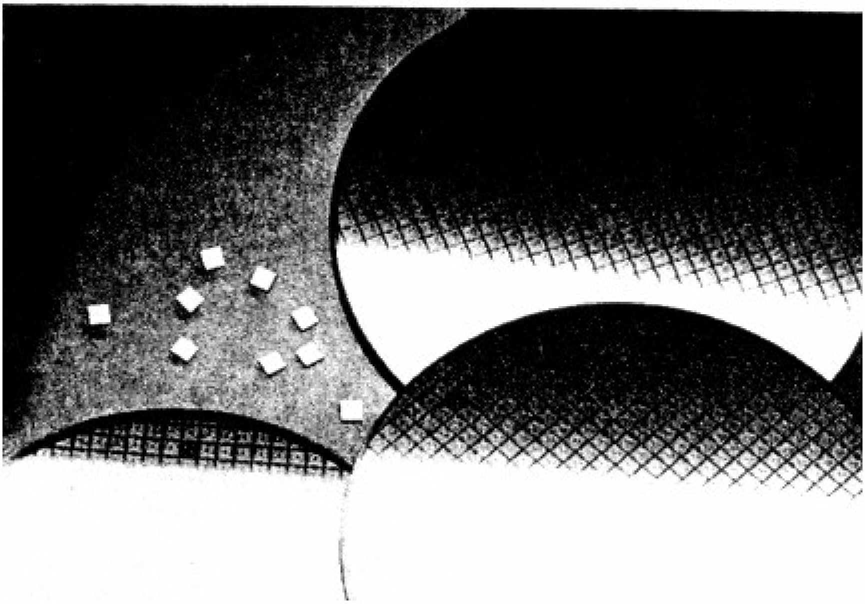


Figure 3-2 Sensitivity of required SRAM price to selected parameters.
Source: Semiconductor Research Corp. (1989).

Processing requirements for different types of devices vary tremendously, affecting the complexity of the plant, the number of processing steps, and the flow of materials. Despite the difficulties of achieving submicron dimensions, DRAM fabrication is much less complicated than that for microprocessors and ASICs. Because DRAM designs tend to be repetitive arrays, a DRAM plant typically produces one design with minor variations, thereby reducing the number of changes necessary in the process and allowing greater scale economies. In contrast, because a microprocessor typically contains both memory and logic devices on the same chip, design complexity is much greater. As a result, microprocessor factories may produce 20 to 30 major design variations at one time. Compared to DRAMs, batch sizes are smaller and material flow is much more complex; while the nature of the individual processing steps is the same, microprocessors require significantly more steps than DRAMs. ASICs represent a still different set of control challenges. An ASIC plant may be producing hundreds of designs, so managing wafer flow and device testing are critical for cost-effective production.



Close-up of silicon wafer and individual chips after processing.
Source: National Semiconductor.

Controlling such complex manufacturing systems to maximize equipment utilization and yields, in a hazardous environment with extraordinary standards for cleanliness and precision, is a daunting management task. Japanese competitors have proven adept at minimizing variability in the process to achieve high yields, and several U.S. producers, most notably Motorola and Intel, have made impressive progress in matching Japanese accomplishments. Using many of the precepts of total quality management—design for manufacturability, preventive maintenance, close relations with equipment and materials suppliers, broad-based training of a skilled work force, etc.—firms are able to achieve higher yields when a new line is opened and to improve yields rapidly.

Labor Costs

Given the sophisticated equipment involved and the importance of maximizing output from that equipment, it is to be expected that skilled workers comprise the greatest proportion of labor costs in wafer fabrication. According to data supplied by Digital Equipment Corporation, skilled labor accounts for 35 percent of production costs for microprocessor and custom device fabrication (Table 3-1). As such, the availability of the skills required is a significant constraint on site selection.

After the fabrication stage, packaging and testing are the final steps in producing a finished chip. Because individual chips are being assembled into packaged semiconductors—instead of entire wafers being processed—this part of the manufacturing

TABLE 3-1 Production Cost Structure for Wafer Fabrication Microprocessor and Custom Devices

Material	15%
Depreciation	15
Labor costs	
Semiskilled	4
Administrative (managers, secretaries, etc.)	7
Skilled and highly skilled technical	35
Other costs, occupancy, utilities, etc.	24
	100%

SOURCE: Digital Equipment Corporation (1991).

process has relied on unskilled and semiskilled labor. In fact, as device technology matures and less sophisticated products are considered, the costs of packaging and testing grow as a proportion of total costs. Most semiconductor assembly has been located in newly industrialized, low wage countries in Asia. Malaysia, in particular, has been very successful in attracting semiconductor assembly operations. The source of its popularity has changed over time, however. Ten years ago Malaysia's attraction was low-cost labor; today the presence of a large number of packaging operations has created a critical mass of talent, experience, and suppliers, making Malaysia an important source of packaging innovations.

Several developments in packaging and testing may change the cost structure of both of these activities. Built-in self-test, a means of testing a chip while it is still on an uncut wafer, should make testing more easily automated. Manufacturers are also beginning to place more than one chip in a single package to create multichip modules. Because of the performance advantages they provide, multichip modules are expected to capture an increasing share of semiconductor packaging; the still-emerging technology is likely to change the economics and technological expertise needed for packaging, which could eliminate the importance of offshore cost advantages.

LOCATION DECISIONS

Since U.S. firms began siting wafer fabs abroad in the 1970s and 1980s, the need to achieve high-capacity utilization and rapid time to market have driven site selections based on proximity to customers, market access, and the ability to operate manufacturing and process technologies to achieve high quality and high yields. Low-cost labor is not a consideration, but high-quality, highly skilled labor availability is.

Recent location decisions taken by U.S.-owned firms illustrate these changes. For example, Digital recently located a microprocessor fabrication facility in South Queensferry, Scotland. The reported criteria for selection were, in order of priority:

- availability of skilled people
- infrastructure (power, waste treatment, etc.)
- market access to the European Economic Community

Workers monitor the manufacturing process in the clean room of a silicon wafer fabrication facility in Arlington, Texas.
Source: National Semiconductor.

- government grants
- operating costs

Other factors falling lower in importance were access to design engineers (those designing circuits for end customers), equipment availability, and access to capital. This last item did not weigh heavily in the decision because Digital has access to capital worldwide.

The fourth item on the list—government grants—has become a controversial factor in site selection decisions; however, as with the Digital illustration, government incentives are not typically the determining factor. A potential site must first have all the major prerequisites—killed work force, infrastructure, and market access—before government incentives can play a determining factor. In Digital's case, South Queensferry is in an area known as "Silicon Glen" where a growing number of semiconductor facilities are also located, not only ensuring skill and infrastructure availability but also providing a track record for Digital's management to consider. As an additional incentive, Scotland offered grants for capital, training, and employment that accounted for an estimated 15 percent of the initial investment in the facility.[18]

This example illustrates two important points. First, government incentives can make a significant difference to a prospective manufacturer, but only when it must choose from a variety of locations that are otherwise similar with respect to market access and access to skilled workers and technologies. Second, although there are certain site characteristics that are essential, other factors, often subtle and unique to particular managers, can be major determinants.

In the 1990s the United States may be viewed more and more favorably as a location for both wafer fabrication and packaging, although many of the sources of technology, processes, and equipment may be Japanese. The drivers are a combination of technology shifts and trade policies. Already several Japanese firms have set up fabrication facilities in the United States, both to gain access to U.S. markets in the face of protectionist trade policies and to exploit exchange rate differentials. As stated above, Japanese firms have also bought existing U.S. firms (most conspicuously those in the semiconductor materials and equipment sector). While such investments might not constitute a site location abroad, per se, the acquisition of foreign capacity represents a de facto decision to move capacity offshore.

CONCLUSIONS

From its examination of the semiconductor industry, the committee offers the following conclusions about cost, site location, and competitiveness.

- Firms must make huge capital investments to be players in the market, but success is secured by maximizing the returns on that investment, not by whittling down the initial outlay. The large capital expenditure makes capital efficiency (short cycle time, high throughput, yield improvements, and quality) all the more critical. If these are anything short of exceptional, a firm may lose a major share of the initial investment, market share, or even the business itself. Market access and access to technologies and capabilities will continue to be the overriding concerns in site location decisions.

- Regardless of how efficient a manufacturer is, unfair trade practices, such as product dumping, can have catastrophic effects when firms find themselves unable to recoup huge capital investments because a competitor is selling far below production costs.
- The semiconductor industry will continue its tendency toward research consortia and joint ventures, motivated by high R&D and capital costs and the need for secure supplier relations and market access. When firms team up to develop and manufacture new device generations, they have the opportunity to learn better ways of manufacturing and of sharing investment risk. The predominance of foreign firms as the preferred partner in joint ventures, however, raises some interesting questions. Is this due to the fact that only foreign firms have the complementary skills and knowledge sought by American manufacturers? Or are government policies, particularly trade policies and local content requirements, driving these decisions?
- Countries are trading market access for semiconductor manufacturing technology.
- Being a successful semiconductor manufacturer means knowing how to manage capital effectively. Domestic manufacturers are at a distinct disadvantage in this respect when either stockholder expectations or depreciation schedules force them to manage capital suboptimally.
- As market access and access to technologies/capabilities continue to determine where semiconductor manufacturers locate their facilities, the United States will be a viable place to make semiconductors in the future. The United States will be excluded as a potential manufacturing location, however, if

1. it cannot provide engineers and skilled technicians in sufficient numbers,
2. the skill base for advanced manufacturing (both in managerial and technical terms) continues to erode as Americans lose market share and thus experience with technology/process-driving devices, or
3. customers for semiconductors—electronics firms—leave the United States in sufficient numbers that manufacturers prefer to follow them abroad.

NOTES

1. For example, the U.S.-Japan Semiconductor Trade Agreement of 1986 established fair market values for certain chips and set goals for U.S. share of the Japanese market.

2. Department of Commerce, *U.S. Industrial Outlook* (Washington, D.C.: U.S. Government Printing Office), 1992, p. 20.

3. Semiconductor world market sales and shares data were provided by the Semiconductor Industry Association, San Jose, California, June 19, 1992.

4. National Advisory Committee on Semiconductors, "Attaining Preeminence in Semiconductors," February 1992, p. 9.

5. U.S. dominance in 8-bit microprocessors (8080, Z80, 6800 series) as well as 16- and 32-bit microprocessors (8086 and derivatives, 68,000 family, and reduced instruction-set computing devices) is a result of U.S. strength in computer architecture of all types.

6. Japanese dominance in microcontrollers (devices in which program software is stored on-chip) is largely a result of Japanese control of the consumer electronics industry. Texas Instruments once held a lead position in this segment with its TMS1000 and TMS1100 products but lost it as the available market shrank, since the Japanese firms that dominate the consumer electronics market tend to buy from their affiliated companies.

7. In 1990, North American companies gained market share for the first time since 1979 (growing from 34.9 percent in 1989 to 36.5 percent in 1990) due, in part, to the strong microcomponent sales of companies such as Intel and Motorola and the free-falling prices for DRAMS. See "Semiconductor Market Share: Dataquest Releases 1990 Preliminary Results," *EDGE: Work-Group Computing Report*, January 7, 1991, p. 9.

8. For example, Motorola is working with Toshiba, Texas Instruments with Hitachi, and AT&T with NEC on design and production technologies for 16- and 64-megabit DRAMs.

9. Michael L. Dertouzos, Richard K. Lester, and Robert M. Solow, *Made in America: Regaining the Productive Edge* (Cambridge, Mass.: The MIT Press), 1989, p. 252.

10. This fragmentation is sometimes viewed as a threat to American firms, particularly when domestic producers are being bought by overseas competitors. For example, the recent debate over Nippon Sanso's acquisition of Semi-Gas, a purchase that would give Nippon Sanso control over 33 percent of the worldwide sales of gas cabinets, was contested on antitrust grounds by the U.S. Department of Justice, but the Sale was cleared in U.S. District Court in March 1991.

11. U.S. Department of Commerce, *Japanese Direct Investment in U.S. Manufacturing* (Washington, D.C.: U.S. Government Printing Office), 1990, p. 17.

12. Robert Neff, Otis Port, and Jonathan B. Levine, "The Costly Race Chipmakers Can't Afford to Lose," *Business Week*, December 10, 1990, p. 186.

13. For example, see Jacob M. Schlesinger, "AT&T, NEC Agree to Cooperate on Basic Chip-Making Technology," *Wall Street Journal*, April 23, 1991; p. 134.

14. National Advisory Committee on Semiconductors, *Toward a National Semiconductor Strategy*, Vol. 1 (Washington, D.C.: U.S. Government Printing Office), February 1991, pp. 9-10.

15. National Advisory Committee on Semiconductors, *Capital Investment in Semiconductors*, A Working Paper (Washington, D.C.: U.S. Government Printing Office), September 1990, p. 2.

16. Richard A. Whisnant, "Semiconductor Manufacturing Cost Analysis: Demonstration of a Required-Price Approach," private communication by the Semiconductor Research Corporation, March 1989.

17. Changes in wafer size have been as large a reason for retooling in the industry as critical dimension reductions.

18. Other common incentives include tax holidays and agreements that obligate the host country to build waste treatment facilities or roads for the prospective manufacturer.

4

Automobiles

With justification, the automobile industry is viewed as a bellwether industry for many of the trends unfolding in manufacturing. Confronted with the challenges of improving fuel economy, cutting emissions, and maintaining market share in the face of rapidly expanding Japanese competition, U.S. automakers have been forced to pursue many objectives at once. Developing and incorporating advanced product and process technologies have been necessities at the same time that reduced manufacturing costs and high quality have become fundamental market requirements. Such daunting and often conflicting demands have stretched resources and skills to the limit, but the success in achieving all these objectives should not be underestimated.

Given these pressures, it would be reasonable to assume that offshore manufacturing could offer attractive advantages, particularly as an effective way to lower production costs; therefore, an analysis of these costs as they affect global site location would be expected to provide useful insights both to managers in the industry and to policymakers. Somewhat to the committee's surprise, however, the assumption appears to be false. There is no apparent trend to offshore manufacture of automobiles. In fact, the dominant trend is in the opposite direction: foreign investment has been flowing into North America on an unprecedented scale.

A brief review of developments in the industry will provide some insight into this process. Unfortunately, reliable production cost data are not available in a form that would allow a cost analysis analogous to those elsewhere in this report. Several recent studies, however, have described important trends in global automaking and include data that suggest the source of differences in production costs and the overwhelming importance of market access in site selection decisions.[1]

BACKGROUND

In many ways the automobile industry is a microcosm of manufacturing in general. It is often the largest single industry in countries where automobiles are manufactured. Because it is such a large component of the economy and a major employment provider, the industry has a long history of government regulation and trade protection. It also illustrates the accelerating pace of technological change: the mechanical precision, electronics, and materials technology imbedded in new cars overwhelm products of 20 years ago, but 1970 models, although more refined, were not that much different from those of the 1930s. Much of this technological change has been driven by environmental concerns, which have affected the auto industry for 20 years and are now spreading rapidly to other industries. Finally, perhaps more than any industry, automaking has been confronted with challenges to traditional concepts of effective manufacturing practices that promise to have a profound long-term effect on how and where cars are built in the next century.[2]

Those traditional concepts of effective manufacturing are based on "mass production," first applied to automobiles by Henry Ford. Ford used mass production to reduce production costs dramatically, thereby creating the mass market for automobiles and dominating global auto production in the early part of this century. Because of its clear advantages, mass production eventually spread to every large-scale producer worldwide but has been refined to meet the unique demands of different automobile markets.

Because the American auto market is both large and, historically at least, homogeneous, and dominated by a few large firms, mass production in the American auto industry is volume driven. It is based on high-volume production on dedicated equipment of interchangeable parts that are assembled on an equipment-paced line by low-skilled workers with very narrowly defined tasks. Costs are minimized through economies of scale, so the need to maximize volume dictates a number of design, engineering, sourcing, and investment practices. For instance, to maximize the output of expensive stamping dies, stamping is typically performed in central locations and parts are shipped to distributed assembly plants, common parts are used in as many models as possible, purchasing decisions are based on the lowest bidder, and investments are driven by the desire to eliminate labor.

This traditional mass production system relies on dedicated equipment and equipment-paced assembly lines to keep production high, which is inherently inflexible. Imposing product differentiation on the system, as the market now demands, tends to increase the difficulty of maintaining control of the system. Some disruptions are equipment based: equipment breaks down, defects may be found only after large numbers of bad parts have been produced, and different machines produce parts at different rates, causing production bottlenecks. The system has evolved to accommodate such disruptions: high work-in-process inventories minimize bottlenecks that could stop production, long product life cycles minimize the need for die changes and other costly and time-consuming disruptions, and high scrap and rework are accepted as inevitable costs of maximizing equipment output and the pace of assembly. The costs of such solutions are overwhelmed by the economies of scale gained by maintaining output.

Traditional mass production is extraordinarily good at low-cost production of undifferentiated items. It is inherently weak, however, in many of the attributes consumers now demand, particularly consistently high quality and product differentiation. To meet these demands—attributes of their market for many years—several (not all) Japanese auto manufacturers have refined a different form of mass production, embodied in the term "lean production."[3]

Developed initially at Toyota and now spreading through the auto industry and others, lean production integrates the manufacturing system to minimize waste, maximize quality and flexibility, and stimulate innovation. Lean production has turned traditional assumptions, measurements, and management of manufacturing in the auto industry upside down. Lean producers engineer flexibility into the production process (e.g., through rapid die changing); expect workers to perform multiple tasks, ensure the quality of their work, and call attention to defects to discover their source (by stopping the line if need be); work closely with suppliers to allow them to determine the most effective manufacturing processes for the parts they supply; and create engineering teams to work on product and process engineering simultaneously. The results are much higher product quality, virtually eliminating inspection and rework; lower production costs; and greater production flexibility, allowing more models to be produced with less production capacity and rapid model turnover.

As these concepts have spread from Toyota to other Japanese manufacturers and, more recently, to U.S. automakers, the competitive advantages they provide result not only in increased market share for lean producers but also redefined customer expectations. Lean production is, therefore, upping the ante of what it takes to be competitive in the automobile industry.

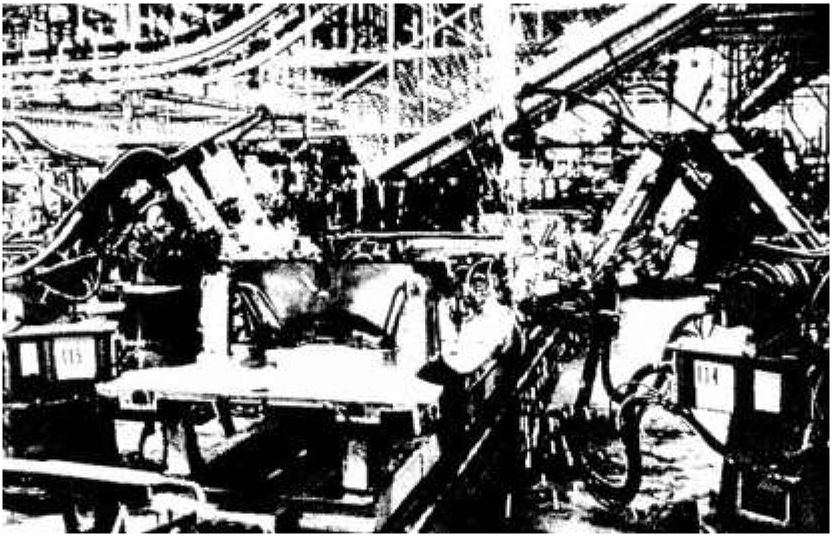
INTERNATIONAL MOVEMENTS OF PRODUCTION CAPACITY

Despite the size of the industry, the ubiquity of its product, and the size of the relatively few firms engaged in automobile assembly, it is only recently that international site location has been an issue for automakers and governments. Because of the history of the industry and the distinct character of demand in different markets, the auto industry has always been home market focused. Although Ford opened an assembly plant in England in 1911 and General Motors purchased Opel in 1925, both ventures were devoted to serving unique European demands and were managed largely independently from their American parents. Only in the past decade or two has the automobile industry begun to globalize; the trend is strong, but progress is still limited. In 1988 Ford was by far the most globalized of the 11 high-volume producers, but it still produced 66 percent of its output in North America; General Motors produced 75 percent of final output in North America. All the Europeans manufactured over 80 percent of their output in Europe, and among the Japanese, only Honda produced more than 25 percent outside Japan.[4] It has only been since 1982, when Honda began assembling cars in Ohio, that the level of Japanese investment abroad has grown rapidly, and the number of Japanese plants—including final assembly, engines, and component suppliers—in North America and Europe continues to rise.

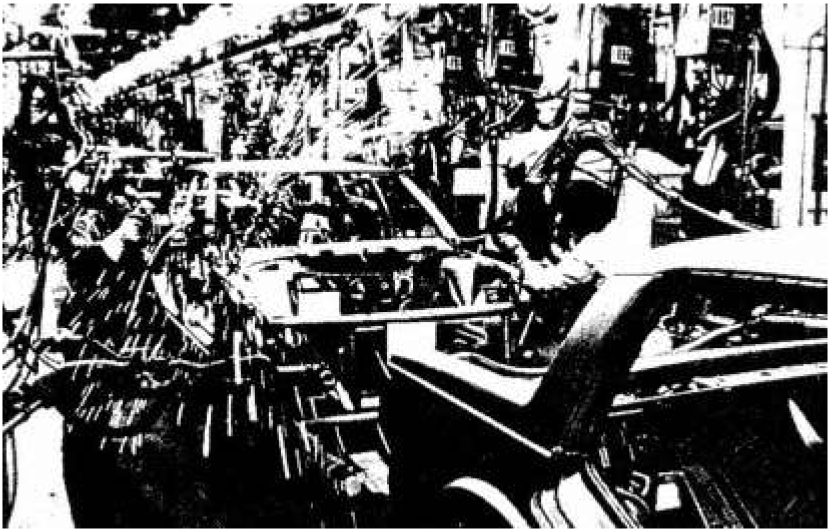
Furthermore, of the 48 million vehicles produced worldwide in 1988, only about 10 percent were produced in developing countries. Although vehicles are manufactured or assembled in about 30 less developed countries (LDCs), and over 60 LDCs produce parts and components, only three—Korea, Brazil, and Mexico—have managed to export much, accounting for over 90 percent of all LDC vehicle exports.[5] Additionally, it is worth noting that Korea's largest auto producer, Hyundai, opened an assembly plant in Bromont, Quebec, in 1989.

These points deserve emphasis because their implications are often lost in the general debate about U.S. competitiveness. There has been very little discernable movement of production out of North America by American producers. True, imports have captured a growing share of the domestic market, which, of course, represents offshore movement of production. And there has been some growth in Mexican production to serve the U.S. market, most notably Ford's Tracer/Escort plant in Hermosillo and Chrysler's Acclaim/Spirit/LeBaron plant in Toluca. However, from the perspective of the focus of this report—offshore movement of production to lower production costs—it simply has not happened. In fact, the only major global shift in automobile production has been Japanese investment in North America, combined with domestic shifts in production by American producers—that is, closures of outdated assembly plants; new investment to modernize existing plants; and greenfield investments, such as General Motors' Saturn plant in Spring Hill, Tennessee.

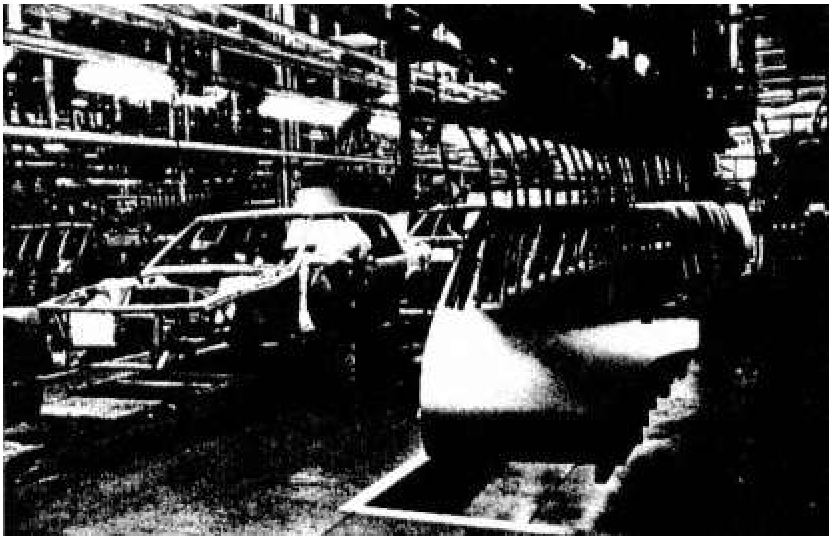
The Japanese have invested heavily in North American production, an investment that ranks as perhaps the largest scale shift of production capacity to a foreign location ever undertaken. Between 1982 and 1992 the Japanese will have opened



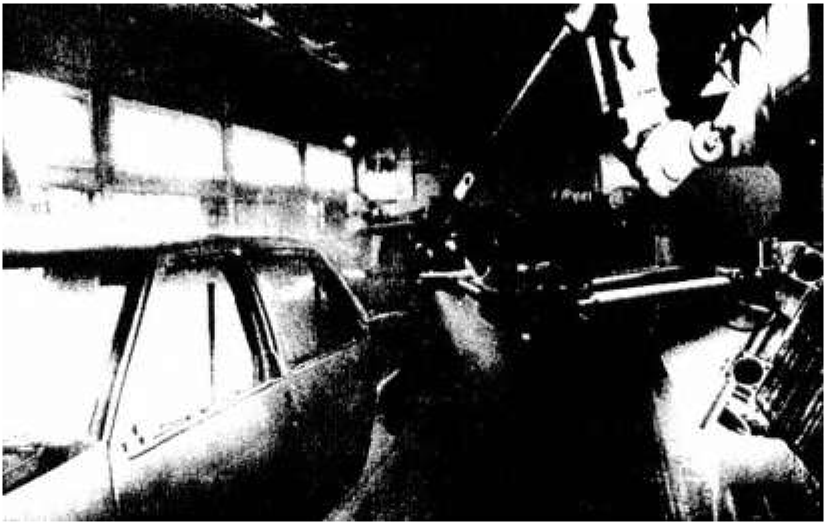
Four computer-controlled robots weld the underbody, one of the first steps in automobile assembly.
Source: General Motors Corporation.



After 18 pairs of robots apply spot welds to the car's unibody, workers perform detail welding. A total of 5,000 welds are used in the full-size car illustrated, 93 percent of them applied by robots.
Source: General Motors Corporation.



Beside the assembly line, doors move on hangers beside the bodies they will join. Front doors and the hood are then added as the "body in white" moves toward the paint shop.
Source: General Motors Corporation.



Robots are used extensively in painting operations, ensuring consistent paint application and minimizing worker exposure to the painting environment.
Source: General Motors Corporation.

eight major assembly plants, creating capacity to build over 2.5 million cars per year in North America.[6] They also have created a materials and parts supplier network in the United States to raise local content over 80 percent in the next few years. Presently there are 66 Japanese-owned steel works, 20 rubber and tire factories, and more than 270 auto parts suppliers. Production equipment is also domestically sourced from U.S. and Japanese suppliers. Sixteen Japanese machine tool companies now manufacture in the United States, along with two convey-or belt manufacturers and two builders of automobile painting equipment.[7]

What has motivated this tremendous investment? The primary factor was the Voluntary Restraint Agreement on exports to the United States. Local production was the only way to continue to build share in the rich American market. The strengthening of the yen in foreign exchange markets reinforced the logic of local production and helped build the conviction among Japanese managers that continuing to rely on Japan as an export platform was no longer viable. A global production base was needed to increase flexibility, market awareness, and customer response. Finally, the Japanese have discovered that they can build cars and parts abroad as well as they can in Japan, and better than most of the local producers, so the risks inherent in local production, particularly those related to work force management, have proven to be minimal. In fact, a local production base provides a better means to leverage the advantages of the lean production system to customize products for different markets; to speed product introductions; and to build knowledge of, access to, and implementation of locally developed technologies.

MANUFACTURING COSTS

Although offshore movement of automobile production has, almost exclusively, been movement by Japanese producers to North America and increasingly to Europe, a brief examination of manufacturing costs will emphasize the point that the critical driver is market access. Assessing manufacturing costs in auto production, however, is extremely complicated. First, good data are difficult to find. When dollar costs are available, international comparisons over time are virtually impossible because additional data on exchange rates, interest rates, model configurations, sources of components, and other factors are not sufficient to make appropriate adjustments. Second, understanding of costs is changing rapidly as the concepts of lean production spread through the industry. The coexistence of mass production and lean production adds to the complexity of assessing production costs in the automobile industry. Third, costs vary widely by model, options, plant age and location, and stage of the business cycle. Generalization across the industry is difficult, and averaging across the diversity of models and components is not very informative. Finally, the situation is further complicated by the high degree of government interference in the global auto market. Trade protection is rife, typically to retard market penetration by Japanese producers; safety and environmental regulations are numerous and, though slowly converging, remain inconsistent across national and state boundaries. Consequently, even more than most other industries, international cost comparisons are problematic. Nevertheless, the data that are available make it clear that *automobile productioncosts are not strongly correlated with geography*.

Why not? The main reason is that Offshore manufacturing locations have little to offer except low-cost labor, but direct labor has become a small part of manufacturing costs. Though the level varies by model size and low-volume luxury models tend to have more hand work, on average direct labor accounts for only 5 to 10 percent of automobile assembly costs, with a combined labor and load of 15 to 20 percent.[8] As a source of cost savings, direct labor does not provide the same leverage as materials, although most materials are purchased parts, components, and subassemblies that have significant imbedded labor content. However, even in automotive parts production (SIC 3714), direct labor is only 15 to 20 percent of production costs and combined labor and load 30 to 35 percent;[9] with parts production as well, the cost of materials offers greater leverage to reduce total costs.

That is not to say there are no opportunities to reduce labor costs. Comparisons reported in a survey of auto plants by the International Motor Vehicle Program at the Massachusetts Institute of Technology reveal broad differences in hours required to assemble comparable cars. The average hours per vehicle in Japan in 1989 were 16.8; for Japanese plants in North America, 21.2; for American producers, 25.1; and for European producers, 36.2.[10] Clearly, there is room for improvement. Just as clearly, superior performance can be achieved in North America using American labor.

The standard approach to reducing labor content has been through automation, and many American managers have explained these differences in hours per vehicle by pointing to relative levels of automation. Despite the fact that Japanese plants tend to be more automated than American and European plants—for example, in Japan 86 percent of welding steps are automated versus 76 percent in the United States and Europe[11]—this explanation is demonstrably inadequate, as more and more managers are realizing. According to George C. Eads, vice president and chief economist of General Motors:

> ... Automation has been proposed as an antidote for high developed country wage costs. It is argued (1) that only by significantly reducing the labor content of motor vehicles can companies manage to retain production in the developed countries and (2) that the only way that labor content can be reduced is through automation.... Thus far at least, the second part of this argument has not turned out to be correct, at least not in the United States.... The cost reductions achieved by North American "transplants" and Ford ... have *not* been obtained through increased automation but instead through improved organization and management of the production process.[12]

Experience corroborates this idea that management, not automation, is the key issue in cost competitiveness. General Motors spent over $40 billion in the 1980s on factory automation. Though improvements in cost and quality have been achieved, the results have not met expectations and much of the realized improvements have been due to management and organization changes, not automation. For instance, General Motors' joint venture with Toyota, the New United Motor Manufacturing, Inc. (NUMMI), achieved major reductions in costs and defects through improved organization and management, not automation.[13] Similar improvements have been achieved at several Ford plants. As the concepts of lean production continue to pervade the industry, average hours per vehicle can be expected to fall further.

As labor content continues to fall through the spread of lean production practices, the critical labor issue shifts away from cost to quality. Workers in lean production facilities are expected to perform a wider variety of tasks in cooperation with fellow workers. Such jobs are in sharp contrast to traditional mass production jobs that are narrowly defined and highly repetitive; they require higher skill and greater initiative. Although such traits are typically thought to be the preserve of advanced societies, several automakers have found workers in less developed countries, such as Mexico, to be both receptive to and highly competent at lean production practices. In fact, Ford's highest-quality plant is in Hermosillo, Mexico.[14] When combined with dramatically lower wage and benefits costs, the productivity potential of low-cost workers would appear to offer an unbeatable advantage.

In reality, the advantage is quite small in relation to total production costs. Even if labor costs were zero, total costs would still be reduced only by 10 percent. High leverage for reducing production costs comes in materials and overhead, which are also dramatically reduced using lean production techniques. Given this reality, the attractiveness of low-cost labor is virtually eliminated in site location decisions, particularly since low-cost locations have few if any other attractors. Markets are small; infrastructure is often weak; supply lines are long. Consequently, auto plants are sited in LDCs to meet local content requirements, not as replacements for home market production. (Mexico, increasingly, is a unique case given recent changes in its local content regulations and the possibility of a North American Free Trade Agreement.)

EFFECT OF FUEL ECONOMY REGULATION

Although it is clear that potential production cost savings are not sufficient to overcome the advantages of producing in the large developed markets, there is an increasing risk that a certain amount of foreign production will be encouraged by the Corporate Average Fuel Economy (CAFE) regulations. All automakers must meet a standard for CAFE, currently 27.5 miles per gallon (mpg), or pay fines of $5 per 0.1 mpg per vehicle sold. However, imports are averaged separately and treated as if manufactured by separate manufacturers, though they must meet the same standard.

As the CAFE standard has become more stringent and automakers begin to use up the credits earned in past years to meet current standards, this separate averaging of imports creates opportunities to manage production to raise a firm's CAFE through foreign production. For CAFE purposes, a domestic car must have 75 percent local content; conversely, cars with less than 75 percent local content are considered imports and averaged separately. Because most imports are small cars that typically exceed the 27.5 mpg standard substantially, automakers can minimize the adverse effects of their largest, least fuel efficient models by averaging them with the imports. They can still meet the standard for imported vehicles but without dragging down the average for domestic products.

The result is that automakers are increasingly likely to source components from abroad to lower the domestic content of their largest cars. For instance, Ford builds its Crown Victoria/Grand Marquis full-size sedans in Canada (a domestic plant for CAFE purposes). Through the 1990 model year it was classified as a domestic car; for 1991, however, Ford opted to lower domestic content under 75 percent by using door trim, instrument panels, and fuel tanks from Mexico; forged upper-front suspension arms from Germany; upper suspension links and shock absorbers from Japan; and tires from Spain. The imported components are sufficient to qualify the model as an import under CAFE regulations. Other automakers use similar strategies. For instance, Nissan maintains the local content of its Sentra subcompact, assembled in Tennessee, below 75 percent to continue its import classification for CAFE, to offset several of its low-mileage imported models.[15]

Two points should be noted. First, as the Ford example illustrates, LDCs have no particular advantage as a source for imported components; location depends on the level of technology of the part and the availability of qualified suppliers. Second, more stringent CAFE standards would increase the incentive to lower domestic content on a broader range of models.

The result could be greater offshore production of components, though final assembly would likely remain domestic.

SUMMARY

Although its international competitiveness is widely debated, the U.S. automobile industry is not an example of an industry moving offshore. Although Ford and General Motors have a strong presence in Europe and produce in many LDCs to meet local content requirements, the bulk of manufacturing for all automakers is still done in the home market. International site selection, for cost savings or any other reason, has not been a significant phenomenon—with one exception: the Japanese have created massive production capacity in North America and are gradually increasing their capacity in Europe.

This pattern of home market production and Japanese direct investment makes it clear that market access is the dominant motivator of site selection in the auto industry. Because only a few markets—North America, Europe, and Japan—provide the combination of skilled engineers, extensive supplier networks, and customer demand necessary to justify large-scale production, the most attractive sites for production are in those markets. Combined with the fact that the auto industry is highly regulated and confronts trade barriers in every major market, it is not surprising that relatively little production is done in LDCs.

What is surprising is the overwhelming degree to which production remains concentrated in the firms' home markets. Ford has progressed further than its competitors in crafting a truly global enterprise, and the Japanese, particularly Honda, are striving to do so. The other major firms, however, remain quite parochial, especially the Europeans. Volkswagen has a plant in Mexico and a strong presence (with Ford) in South America,[16] and Volvo assembles a small number of cars and trucks in Canada, but Renault withdrew from North America when it sold American Motors to Chrysler, and Peugeot and Rover recently withdrew from North America because of poor sales. These firms are missing important opportunities to learn from diverse markets; to leverage products between markets (e.g., as Honda is doing with the Accord coupe, which is built in Ohio and sold as a mass market model in the United States but is exported in small numbers to Japan and sold as a luxury model with higher margins); and to access and incorporate new technologies nimbly. Capturing these opportunities will provide tangible advantages in the market.

NOTES

1. We cannot match the depth or detail of these studies, but highly recommend references such as James P. Womack, Daniel T. Jones, and Daniel Roos, *The Machine that Changed the World* (New York: Rawson Associates), 1990, and Michael L. Dertouzos, Richard K. Lester, and Robert M. Solow, *Made in America: Regaining the Productive Edge* (Cambridge, Mass.: The MIT Press), 1989.

2. The following is a brief synopsis of an extensive analysis of mass versus lean production in *The Machine that Changed the World*.

3. Lean production is the term used by Womack, Jones, and Roos. The concepts are known by several names, however, such as the Toyota Production System. Many of the practices embodied in lean production are also well known, such as "just in time," simultaneous engineering, and quality circles.

4. Womack et al., op. cit., p. 214.

5. Ioannis Karmokolias, "Prospects for the Automotive Industry in LDCs," *Finance and Development*, September 1990, pp. 47-49.

6. It is interesting to note that this increase in Japanese production capacity has been almost exactly offset by lower exports from Japan (1 million units) and the lost output of plants dosed by General Motors and Chrysler since 1987 (1.7 million units). See Womack et al., op. cit., p. 245.

7. Martin Kenney and Richard Florida, "How Japanese Industry Is Rebuilding the Rust Belt," *Technology Review*, February/March 1991, pp. 25-28.

8. The committee's estimates are based on Department of Commerce data for SIC 3711 contained in the 1987 Census of Manufactures. The most recent data available are for 1987.

9. Ibid.

10. Womack et al., op. cit., p. 92.

11. Ibid.

12. George C. Eads, "Geography Is Not Destiny: The Changing Character of Competitive Advantage in Automobiles," presentation to the Committee on Comparative Cost Factors and Structures in Global Manufacturing, September 7, 1989, pp. 17-18.

13. Eads, op. cit., p. 21.

14. An excellent discussion of the productivity and quality capabilities of the Mexican work force can be found in Harley Shaiken, "Automation and Global Production," Monograph Series, 26, Center for U.S.-Mexican Studies, University of California, San Diego, 1987.

15. Both domestic and foreign automakers actively manage the domestic content of their Vehicles, not only for CAFE requirements but also for customs and tax purposes. The same vehicle can be classified as both imported and domestic by different federal agencies. See Gregory A. Patterson, "Foreign or Domestic: Car Firms Play Games with the Categories," *Wall Street Journal*, November 11, 1991.

16. Volkswagen supplies Golf/Jetta models to the U.S. market from its Puebla, Mexico, plant and the Fox model from its plant in Brazil.

5

Conclusion

To assess the relative role of cost differentials and other factors in global manufacturing, the committee has relied on its members' experience in major multinational corporations, received input from experts in industries not represented on the committee,[1] and reviewed relevant literature and statistical information. By focusing on three of the most internationally competitive manufacturing industries, the committee has tried to highlight the extent and importance of the developments taking place in global manufacturing. Although. generalizations must be approached cautiously in an economic activity as diverse as manufacturing—no two companies are alike, let alone whole industries—the committee believes its analysis has illustrated many of the forces at work in global factory site selection.

WHAT ATTRACTS MANUFACTURERS?

Based on its analysis of the onshore/offshore decision-making process, the committee has identified several attributes that attract manufacturers to a given location. These attributes fall roughly into three categories: access to low-costs, access to technologies and capabilities, and access to markets. Depending on how a firm understands costs and cost reduction, there are a variety of attributes that might make a location attractive for a new production facility. The attributes that are attractive strictly because they determine the resources a firm must expend to make its product are included under the general heading of “Access to Low-Costs”:

Access to Low Costs

- access to reduced factory costs in terms of direct labor rates, materials costs, and load costs that include indirect labor and fringe benefits
- access to low transportation costs, duty payments
- access to low-costs associated with decreased inventory requirements, a function of defect rates, work in process, and proximity to and relations with customers and suppliers
- access to reduced distribution and sales costs

Although low production costs have long been attractive to manufacturers, the need to ensure access to advanced technologies and production capabilities is a relatively new phenomenon. Research and development capabilities have spread broadly around the globe, and no manufacturer can afford to rely Strictly on the domestic market to provide needed technology. Clearly, imports of equipment can ameliorate the need to venture offshore for new technology, but many manufacturers have discovered that timely access to technology often requires a physical presence in the market where it is developed. The same is true for some types of manufacturing capabilities: companies need not only access to advanced equipment but also the opportunity. to access the management and operations practices and knowledge and skills needed for effective utilization of the equipment. Consequently, access to technologies and capabilities is becoming an increasingly important attractor of manufacturers:

Access to Skills, Technology, and Capabilities

- access to component technologies
- access to design systems
- access to process equipment
- access to work force skills (management skills, engineers, technicians)

Finally, manufacturers choose sites for production facilities as a way to cultivate new markets. This approach to expanding the business (1) offers new sources of revenue, (2) enhances exposure to a new customer base for more timely knowledge of consumer preferences, (3) provides opportunities to preempt competitors' revenue from uncontested markets, and (4) enables the firm to compete directly, in the same environment, against competitors that may have learned to cut costs more efficiently or to add more value to their products. Taking full advantage of these potential benefits sometimes requires building manufacturing facilities in foreign markets. Factors that would affect a decision to move manufacturing offshore to gain access to foreign markets include:

Access to Markets

- avoiding import duties, tariffs, and other trade barriers
- meeting in-country value-added requirements
- closeness to customers and suppliers, better understanding of the market, faster response to the market
- benchmarking products and processes against world-class competitors to improve management practices, learn about new technologies, and build skills

All of these attributes are attractive because they fit into a firm's overall strategy for maximizing total business potential (and are reflected in the model on page 14). However, the draw of each attribute is modified by the perceived associated risk—a concern in any site selection decision. By moving manufacturing functions abroad, a firm risks:

Risk Factors

- losing expertise in technologies
- losing expertise in manufacturing processes
- losing management skills
- losing control over product quality and development cycles

These risk factors are not always well understood and are typically difficult to quantify, but they need to be a fundamental part of the calculus behind any decision to locate offshore.

Although a huge number of factors affect any site location decision, only a few tend to dominate in a given situation. For example:

- Semiconductor manufacturers have built wafer fabrication facilities in Europe in order to comply with local content requirements. (*Accessto Market*)
- IBM produces flat panel displays in Japan in order to gain access to a product and process technology infrastructure unavailable anywhere else in the world. (*Access to Technology and Skills*)
- AT&T builds consumer telephone instruments in Thailand in order to take advantage of low-cost direct labor, engineers, and materials. (*Access to Low-Costs*)

Which variable will dominate any one decision depends on:

- the product (e.g., flat panel displays vs. breakfast cereal), and the stage of production (e.g., semiconductor fabrication vs. assembly)
- the company (e.g., U.S. company vs. a Japanese company)
- time (e.g., Digital's manufacturing strategy changed significantly between 1965 and 1985)[2]

Having examined site location decisions in the wider context of corporate strategies to maximize total business potential, the committee found that cost is clearly no longer the only factor in site location decisions and today, in the cases examined, is not the dominant factor. Market access and access to technology and capabilities are often more important drivers of factory site selection decisions.

ABANDONING MYTHS

A critical issue in the factory location decision process is the degree to which current decisions benefit from the lessons of past decisions and are based on current realities in the global market. Too often, management decisions are based on "common wisdom" that might have been true once but no longer holds, as well as information that is incomplete and misleading. An effective way to illustrate the general level of misunderstanding within the manufacturing community is through discussion of a series of myths.

Myth 1: Automate, Emigrate, or Evaporate

The premise behind this commonly heard statement is that U.S. labor costs are too high to compete with foreign manufacturers. To survive, U.S. manufacturers must get the labor content out of their products, through extensive application of automation or by shifting production offshore to inexpensive labor locations. Though true for some products, this premise cannot be generalized; in many cases it is simply outdated.

The committee's analysis of the consumer electronics, semiconductor, and automobile industries indicates that direct labor is a diminishing proportion of total manufacturing costs, at least for the large corporations examined. Managers need to assess accurately their manufacturing costs to determine their true direct labor costs before moving production abroad or investing in automation technology.[3] Certain processes, such as semiconductor packaging, will prove to be labor-intensive, but an accurate assessment is likely to indicate that reducing direct labor is no longer a high-leverage strafes, for cost reduction for most large firms. As a result, moving production offshore simply to save labor costs may incur management and logistics costs that outweigh the labor savings.

The primary reason for the diminished importance of direct labor costs, of course, is that advances in manufacturing processes and automation have been very successful in reducing the direct labor requirements in modern manufacturing operations. Continued technological advances will no doubt further displace direct labor, especially low and semiskilled workers, but with rapidly diminishing returns. Future investments in advanced manufacturing technologies will be justified, even required, for the strategic advantages they provide—in terms of product customization, rapid time to market, and improved quality—rather than the labor they save.

Technology investments, however, also require close scrutiny and should not be viewed as a panacea. As company after company has learned, it can be a costly mistake to automate a process that is not in control, and gaining control often precludes the need for automation. Effective management strategies, organizational relationships, work flow, and quality procedures often are the source of competitive advantage, not input cost differentials per se. Neither automation nor low-cost labor can compensate for a poorly managed, poorly controlled manufacturing process.

Myth 2: Manufacturing Offshore Cuts Costs

A widely held assumption in U.S. industry is that manufacturing abroad or sourcing manufactured goods from foreign suppliers lowers costs. Often, plant location decisions are based almost exclusively on cost assessments, with an overemphasis-on wage rates. The accuracy of the assumption, however, varies widely.

Sometimes offshore manufacturing is less expensive. For some products where labor content is still substantial (e.g., semiconductor assembly), offshore production can cut labor costs as much as 90 percent and total costs as much as 30 percent. As long as the cost structure for these products holds, almost any level of cost advantage will attract manufacturers to "low-cost" manufacturing environments, particularly when margins are low (often the case in mature products).

The cost advantage of offshore manufacturing does not always flow from labor cost differentials, however. Manufacturers may find that access to lower-priced materials, for example (as was demonstrated in the AT&T study), provides greater leverage to lower total manufacturing costs. Offshore management culture may be a source of cost advantage as well: management methodologies that improve quality, for example, can also drive up productivity and lower costs. When the domestic corporate manufacturing culture is too set in its ways to make methodological advances, firms will go abroad to find managers who can immediately be trained in world-class manufacturing practices (or who practice them already). This dynamic has been demonstrated by a number of firms moving to Asia in order to greenfield management. Because management systems are a "portable" cost advantage (lean manufacturing, for instance, is successfully practiced in the United States), this source of cost cutting cannot be assumed to be the exclusive province of offshore manufacturing.

Management differences aside, inexpensive labor does not assure low-cost production. Toshiba, for example, found that it could manufacture color picture tubes less expensively in the United States than it could in Japan (even when Japanese labor costs were lower). Exchange rate differentials, along with changes in trade status, can have profound effects on the cost advantages of a given manufacturing environment. Offshore manufacturing can also have hidden cost disadvantages. In assessing the cost of sourcing abroad or locating capacity offshore, firms must recognize the cost of low productivity, shipping and warehousing costs, quality lags (including inspection regimes), and slower response times. Often these hidden cost factors can make onshore manufacturing the less expensive option.

Myth 3: Sourcing from Foreign OEM Suppliers Is Preferable to Building Internal Capacity

Rapidly changing market conditions, either due to intense foreign competition or emerging new opportunities at home or abroad, often create situations in which firms need new or different manufacturing capacity. For many reasons, such firms may not have the resources or expertise to modify existing capacity or to establish plants abroad, so they turn to foreign OEMs to supply their needs. Such a strategy can be a highly effective short-term expedient: (1) it gets a product to market faster than building new capacity, (2) it offers more flexibility because OEM arrangements can be canceled and shifted, and (3) it is less expensive because it requires little or no capital investment.

Many U.S. firms, including AT&T, General Motors, Ford, and Chrysler, have used OEM relationships to great advantage, both in the United States and in foreign markets. Such arrangements help meet changing demand conditions rapidly, provide a mechanism to gauge market demand before investing in wholly owned capacity, and provide some experience in a market or product line that may be unfamiliar.

The disadvantages of OEM relationships tend to emerge when they cease to be short-term expedients and become long-term strategies. First, long-term objectives of the OEM may be different, and at cross purposes, to those of the customer. Their interest in the relationship may be to gain design, manufacturing, and marketing experience in order to become an effective competitor. Examples of Asian OEMs becoming competitors with their customers abound in products such as cameras, consumer electronics, photocopiers, and cars. Second, firms that. rely on OEMs lose the opportunity to gain experience in manufacturing those products and to build potentially critical engineering skills. Third, because the OEM controls the manufacturing process, it controls the pace of process improvement that could result in lower costs and higher quality. Finally, even if the customer firm can match the OEM's production costs, it would still pay the OEM profit.[4]

Considering these disadvantages, it is clear that OEM relationships must be carefully managed. The effectiveness of the relationship depends on the specific companies and products involved, the control of information between the firms, the time frame, and the objectives of the firms in entering the relationship. Except in situations of highly compatible objectives, the risks embodied in the disadvantages mount over time. Particularly if the customer's motive is long-term investment avoidance, OEM production will likely be a disadvantage.

Myth 4: Moving Offshore Is a Quick, Expedient, Reversible Solutionto Transient Competitive Pressures

Many companies move manufacturing capacity abroad, through investment or OEM sourcing, with the intent of repatriating production after further R&D creates the next-generation product or process. This intent, however, is often difficult to fulfill for several reasons. First, an OEM contract can be a large part of a supplier's business. This means OEMs will always try to make it worth the customer's while to stay in the relationship; eventually, the customer becomes dependent. The initial OEM relationship can also become so comfortable that it is easy for the customer to make new product and process development a low priority. This is a disadvantage if the customer loses the requisite skills to leapfrog competitors.[5] Arguably, these factors played a major role in the demise of the U.S. consumer electronics industry.

Investing abroad can also force changes in corporate strategy, changes that are not foreseen when the initial decision to move offshore is made. If no strategy exists to integrate the new capacity into the firm's manufacturing system, the offshore plant can become more of a burden than an asset. If production schedules are not closely managed, for instance, the firm can end up with products it cannot sell because of demand changes since the order was placed.

An offshore presence can bring about positive long-term advantages, however. Once offshore, a company may find unexpected learning opportunities in having a foreign plant. Organizational systems, supplier relations, and other methodological innovations can result in higher quality and other benefits that can be transferred to domestic plants. Further, experience with offshore manufacturing can expand a firm's vision of its own manufacturing system, spurring it to build global manufacturing capacity. For instance, by benchmarking its domestic operations against its offshore plants and suppliers, AT&T has identified specific areas for improvements and mechanisms to improve.

Myth 5: The Role of Offshore Plants Is Fashioned by Communication Barriers

Two views of offshore plants are common. One is that communication is so difficult that foreign plants can only be suppliers of labor-intense products or components, performing the manufacturing function cost-effectively. The other view holds that communication barriers are such that, given the need for integration of manufacturing with design, engineering, and other functions, offshore plants inevitably become self-contained product development and production centers, thereby shifting skilled engineering jobs abroad. Examples of both views abound in different companies, and the role of foreign plants can shift over time within companies. Both views are overstated.

Effective management of manufacturing operations and new product realization depends on factors such as maintaining effective communication across functions—design, engineering, manufacturing, marketing, R&D—and keeping processes under control. Given the opportunities for effective communication provided by modern telecommunications technologies, there is no reason that global manufacturers cannot integrate far-flung operations into an effective system. For instance, Japanese automobile manufacturers combine marketing information and product design from the United States with engineering and manufacturing expertise in Japan to produce cars for the American market in a timely manner; the Toyota Camry and Mazda Miata are examples. Similarly, AT&T combines design, engineering, and manufacturing expertise from domestic and Asian operations to speed new product introduction.

Having a strong understanding of the total manufacturing system and maintaining a high level of control over that system allow firms to take advantage of and coordinate expertise wherever it resides. Offshore plants need not be confined to production, thereby ignoring useful expertise that can contribute to the firm's total operations, or self-contained and therefore not benefiting from expertise elsewhere in the firm. Increasingly, technologies will allow real-time communications and seamless integration of functions wherever they reside, provided management practices, organizational structures, and corporate cultures encourage and profit from such integration.

AFTER MYTHS: RETHINKING COSTS, COMPETITIVENESS, AND ATTRACTIVENESS

Because site location decisions are driven by a variety of forces (not just cost factors that are widely misunderstood), it is necessary to find a new way of thinking about what kind of and how much manufacturing the United States can attract. More importantly, such a shift in thinking is necessary if government and the manufacturing community are to envision a "desired state"—one in which the United States is a leading player in the global economy and is attractive to a variety of manufacturing industries that serve the needs of consumers, manufacturers, and the continuing health of the national economy. To help explain both its conclusions and the "desired state," the committee created the model shown in Figure 5-1.

The model has two axes. The vertical axis is the manufacturing value continuum. At the bottom end are low value-added manufacturing activities, characterized by a high degree of direct labor, low skill levels, and low wages. At the top end of the continuum are high value-added manufacturing operations, those characterized by high skill levels and high wages.

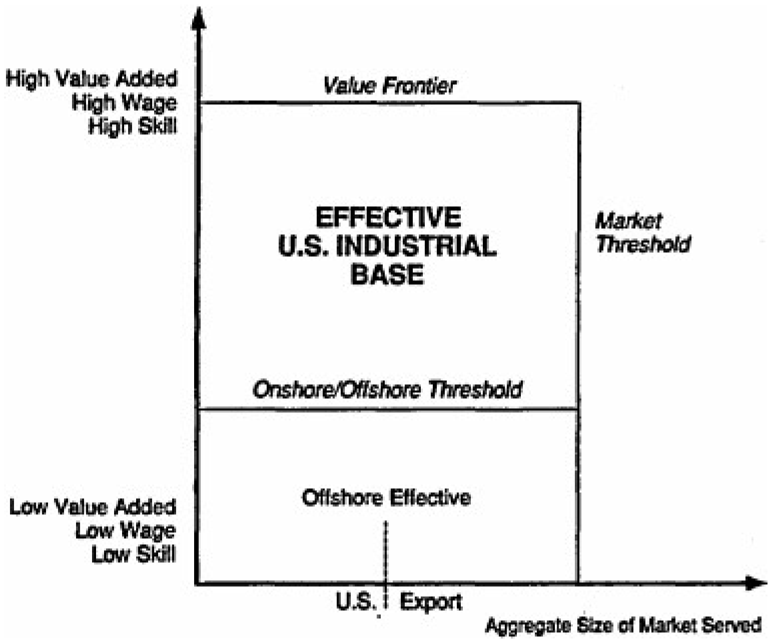


Figure 5-1 The effective U.S. industrial base.

At a given time, there is a certain threshold along this continuum under which the U.S. industrial base cannot be effective. Below the onshore/offshore threshold the wage level necessary to sustain a worker at the U.S. standard of living exceeds the value being added in the manufacturing process. In other words, the manufacturer cannot attract sufficient domestic workers at a wage it can afford to pay. These manufacturing activities are done more effectively in newly developing economies. This line can move up or down depending on the effects of a variety of factors, such as technological change, changes in exchange rates, and changes in tariff barriers.

There is also an upper boundary along the value continuum. This is the value frontier—the area in which manufacturers are exploiting new sources of value-added. The frontier is continually expanding as firms, spurred by competition, find new ways of adding value that the market will recognize. Whether the U.S. industrial base can be effective on this expanding boundary is affected by several factors, discussed below.

The horizontal axis in the model defines the size of markets (along the value continuum) that can be served from the U.S. industrial base. Obviously, the total world market size constrains how far out the market threshold can be moved. In certain areas the market may be extremely large, but the U.S. ability to serve it is limited. To the extent that markets are growing in the areas that the U.S. industrial base can add value for which customers will pay (i.e., those areas above the onshore/offshore threshold), the lateral size of the region in which the U.S. industrial base is effective expands.

There are forces at work that are constantly changing how this system of boundaries and thresholds is arranged. The onshore/offshore threshold, for example, is affected by several forces, some inherent to the system such as exchange rate fluctuations and changing wage differentials, others dependent on innovations in individual firms, advances in technology, or changes in the character of different manufacturing locations.

The committee has identified several forces that can drive the onshore/offshore threshold down, thereby decreasing the minimum value-added that can be justified at the domestic wage levels. The first is the appearance of new manufacturing methodologies such as lean production that allow products to be made at lower cost while adding the same or greater level of value. Although offshore locations such as Japan had a competitive advantage when they invented such methodologies (and some would argue that their cultural environment is more suited to this methodology), the success of “transplant” auto manufacturing in the midwest shows that all locations—including the United States—can potentially overcome wage differentials by managing production more effectively. Whether a country exploits this advantage, however, is a different matter. Just because the U.S. industrial base can be effective in a certain area does not mean that U.S. manufacturers (domestic and foreign) are guaranteed market share. In this model the area of U.S. effectiveness represents the possibility of effectiveness, not the reality of market share (which could be garnered by other nations that may also potentially be effective in those areas or that are more competitive manufacturers in the United States):

The threshold can also be driven up or down by exchange rate differentials. In the late 1980s the weakening of the U.S. dollar drove the threshold down, making the United States a less expensive place to manufacture. In this context the U.S. environment actually becomes "low-cost," contrary to commonly held assumptions. The analysis of Toshiba's manufacturing costs attests to the impact of exchange rate differentials on the effectiveness of manufacturing in the United States. (Although Toshiba's motive for locating production in the United States was to assure access to the U.S. market, the New York plant is in fact a low-cost facility at exchange rates prevailing since 1987.)

There is also a natural tendency for the onshore/offshore threshold to drift downward. Cost advantages of offshore manufacturing are usually transitory for a given location, as seen, for example, in the rising wages and labor shortages in newly industrialized countries. An extreme example of this dynamic are efforts in Singapore to move blue collar production to Batam Island and turn the onshore labor force into commuting managers. Though the global pattern of economic development varies widely, many countries that were once "low-cost" develop (they accumulate wealth, expertise, and higher expectations, and their wage levels rise), diminishing the effective wage differential with developed nations such as the United States. This movement makes offshore manufacturing a less effective alternative to staying in the United States.[6] This dynamic of convergence (which drives the onshore/offshore threshold down) is further exaggerated by the tendency of developing nations to trade market share for technology. As new technology flows into these low-value-adding locations, they develop more rapidly, evolving a skill base and infrastructure that will sustain future, higher-value-added manufacturing activities.

The onshore/offshore threshold is supported or driven up by several forces as well. For example, the AT&T cost analysis demonstrated that materials cost differentials significantly impact the total cost of telephone manufacture, to the point where locating offshore or outsourcing was the obvious choice. While direct labor is decreasing as a proportion of manufacturing costs (thus depressing the onshore/offshore threshold), the concomitant rise in the proportion of materials in the cost of goods sold (COGS) means that international differentials in the cost of materials can drive. manufacturing offshore just as labor differentials once did.

Offshore manufacturing will remain attractive for a wider range of products as long as there are differences in manufacturing cultures as well. In the AT&T study an important motive for moving offshore was that it provided an opportunity to restructure operations immediately that were not operating at world-class standards onshore. This practice of greenfielding management offers significant short-term cost advantages when the domestic corporate manufacturing culture makes immediate methodological manufacturing improvements difficult.

A final critical factor affecting the onshore/offshore threshold is trade policy, though the pressure it exerts may be upward or downward. Tightening market access through higher tariffs or import restraints makes U.S. production more attractive to both local and foreign producers. The risk, of course, is that retaliation in export markets will encourage offshore movement by U.S. producers, thereby shifting the threshold upward. In a complex global economy, the net effects of competing national trade policies are difficult to discern. However, by ameliorating competitive pressures in the U.S. market, trade protection also risks sapping the market vitality that drives technological and methodological improvements that can lower the threshold in the long-term.

Another threshold that moves over time is market threshold—the size of the market that can be effectively served by firms manufacturing in the U.S. environment. This threshold expands (moves to the right) when (1) the U.S. market grows or is better served by a local manufacturing presence, or (2) foreign markets grow that can be effectively served from the United States.[7] The U.S. market is already attracting manufacturers because of its size and the relative affluence of its consumers. Toshiba's presence in the United States (color picture tubes) and the automobile "transplants" clearly attest to the powerful draw of the U.S. market.

The quality of the U.S. market—the sophistication of consumers, pace of technological change, and intensity of competition—can also draw foreign manufacturers, even when alternative locations provide lower manufacturing costs. This is the effect of a state-of-the-art market, where manufacturers compete with world-class peers for a group of sophisticated, demanding customers. Access to such a market can be a boon for manufacturers, beyond what might be gained from whatever markets could be served, because it helps them hone their manufacturing skills (e.g., Ford's adoption of lean manufacturing principles after competing with Japanese automakers manufacturing in both Japan and the United States). Further, the inflow of new ideas can have a positive effect on the manufacturing infrastructure (e.g., the improvement of U.S. auto part suppliers dealing with Japanese "transplants"). However, it is important to recognize that the benefits of a large state-of-the-art U.S. market will not necessarily accrue to U.S.-owned firms. Foreign firms manufacturing in the United States may be in a better position to benefit from those market characteristics.

Factors that would push this market threshold out by encouraging a state-of-the-art market include (1) encouraging free trade and open competition in the U.S. market; (2) eliminating unfair trade practices (such as product dumping) that destroy the integrity of the market; (3) encouraging foreign direct investment, thereby enlarging the field of local competitors; and (4) allowing interfirm cooperation of all sorts (both domestic and foreign), thereby increasing the means available to local manufacturers to adapt to new competitive challenges. In a state-of-the-art market, firms must also be guaranteed access to export markets. The more demands and competition to which a manufacturer can be exposed—at home and abroad—the greater the opportunity for improvement and increased competitiveness.

The market threshold can also recede, for instance, if the U.S. market for manufactured goods were to shrink or if U.S. manufacturers could not serve foreign markets. because of trade barriers. If the quality of the U.S. market were to deteriorate, in terms of manufacturing infrastructure (supplier base, knowledge base) or loss of open, vigorous competition, the threshold would move to the left.

U.S.-based manufacturers have often had an advantage over manufacturers in other locations because advanced technologies and manufacturing methodologies (once Taylorist mass production) were relatively unparalleled abroad. As manufacturing technologies and methodologies diffuse, however, (forces that continue to eliminate the differences between manufacturing environments as manufacturing globalizes), the effective sphere of the U.S. industrial base will increasingly come to be defined by the size of the world market that can be serviced from within the United States (an attribute that currently attracts manufacturers) and the learning opportunities available to those competing in the U.S. market (which will attract the manufacturers of the future).

There is a third set of boundaries that deserves attention: the bottom and top segments of the world manufacturing industrial base. The bottom segment of the base is slowly moving upward as direct labor-intensive, low-skill operations become increasingly rare in manufacturing (although as the studies of the semiconductor and consumer electronics industries show, certain operations such as assembly are still direct labor-intensive and will likely remain so for several years). That bottom segment is also driven up by improvements in manufacturing methodology that effectively let manufacturers add more value while using less resources (labor, materials, overheads). As manufacturing continues to become more sophisticated, and skill levels, wages, and standards of living continue to rise around the world, cost differentials will stop determining how much value a firm can add in a given location. This trend is already apparent in semiconductor wafer fabrication, where cost differentials on huge investments are of secondary importance to the strength of the local infrastructure, particularly skill levels (the real determinant of how efficiently value can be added). In this and other industries, the quality of the workers, the strength of the local infrastructure, and the ability of managers to control the total manufacturing system let manufacturers add value more efficiently, effectively metamorphosing a previously low-value-added, direct-labor-intense process into one in which greater value is added with less effort: high-value-added mass production.

Movements on the top boundary—the value frontier—are especially significant to U.S. manufacturers. The value frontier, as previously defined, is that area of growth where new kinds of value are being added that customers will pay for. That value might flow from technological innovations, new or improved product design, better product performance, higher quality, features that are uniquely suited to individual customer preferences, or product availability (to name a few).[8] Since future market growth (lateral expansion) is, by definition, at this end of the manufacturing spectrum, there are obvious benefits to retaining a dominant position in this area.

Growth on the value frontier can be encouraged by a complex of several factors. First, a state-of-the-art market encourages manufacturers to find new and creative ways of adding value. Historically, U.S. manufacturers have been strong in this respect, literally inventing new sources of value that will determine customer preferences in future competition. A broad base of innovative, highly skilled personnel has, historically, enabled American firms to be pioneers of the value frontier. The skill base (both technologically and methodologically speaking) will likely define the ability of the American industrial base to continue moving forward and pioneering new forms of value, creating new markets for products manufactured within its borders.

But American industry is no longer alone on the value frontier. Effective management practices—in particular, lean manufacturing-have been skillfully exploited by foreign manufacturers. Product quality, availability, and customization have all become market standards (i.e., customers now demand them) because offshore management practices allowed manufacturers to create and offer these new kinds of value (or at least make them affordable). Just as American firms had done before them, offshore manufacturers are clearing new ground on which to compete. These methodological innovations are significant, and must be embraced by American manufacturers. A U.S. industrial base that cannot learn from competitors—particularly if it ignores offshore innovations simply because they are "foreign"—will be denying itself the very opportunities it should be aggressively seeking out. While obvious, the point needs to be reiterated: only an American manufacturing base that is eager to learn from anyone, anywhere, will be competitive and effective in the long-term.

Those factors that might drive the value frontier down, or rather, retard U.S. progress on this front with respect to offshore competitors, are of two kinds. First, there must be an infrastructure of skills, suppliers, and technology to sustain growth. If this infrastructure deteriorates because innovation has migrated abroad, the value frontier will become a value threshold: there will emerge a level of value above which the U.S. manufacturing base cannot effectively sustain manufacturers. Signs of this are already apparent in some sectors, such as semiconductor materials. A second factor that might limit U.S. industrial growth in high-value-added industries would be an inability of manufacturers to get an adequate return on large R&D investments. Again, the semiconductor industry offers a telling example: the inability of U.S. firms to get adequate return on the huge investment required to stay in the DRAM business forced them to leave the market almost entirely. Product dumping, combined with a lack of management skills needed to squeeze high yields out of semiconductor wafer fabrication facilities, contributed to a U.S. environment that virtually prohibited domestic manufacture of these devices.

TOWARD A DESIRED STATE

As the model (Figure 5-1) demonstrates, there are three possible thresholds or boundaries that define the size of the effective U.S. industrial base: the onshore/offshore threshold (bottom), the market threshold (right), and the value frontier (top). The desired state is one in which the effective U.S. industrial base is expanding in areas that contribute both to a high U.S. standard of living and to the long-term viability/expansion of that base. To expand the effective base, U.S. corporate and government policies can push back any of the three boundaries (the onshore/offshore threshold, the market threshold, and the value frontier). Clearly, it is most desirable to keep moving the value frontier up and the market threshold to the right. This will increase the proportion of the global market best served by the U.S. industrial base.

As mentioned previously, the United States has historically been dominant on the value frontier. Ironically, it is perhaps the very skills that brought it there —technological and intellectual innovation—that have served to bias U.S. manufacturers toward purely technological sources of value, away from emerging methodological sources that have been so effectively exploited by offshore manufacturers. U.S. manufacturers cannot afford to ignore methodological sources of value. While there is evidence that environmental cost factor differentials and unfair trade practices have contributed to dwindling U.S. competitiveness in certain frontier industries, the fact remains that effective management and methodological innovations are decisive advantages in global competition.[9]

To expand the value frontier, U.S. manufacturers (foreign and domestic), must understand that it is necessary but not sufficient to bring manufacturing operations up to world-class standards. In doing so, manufacturers will have access to increased revenues and market shares, both of which will feed other vital sources of value that require timely, aggressive investment (i.e., technological or design innovation). The historical strength of the U.S. industrial base—technological innovation—can still be a source of tremendous growth on the value frontier. It will take excellent management and a highly skilled work force, however, to ensure that growth.

Another direction in which the U.S. effective industrial base can expand is to the right—developing a large, accessible, state-of-the-art market that attracts manufacturers from all around the world (preferably in the high-value-added areas) and supports a highly skilled, well-compensated domestic work force. As described previously, essential to growth in this area are actions that (1) increase the mobility and skill level of the work force; (2) encourage foreign direct investment and interfirm cooperation (among firms of all nationalities); and (3) discourage unfair trade practices such as collusion, asymmetrical market access, and product dumping.

Finally, the effective U.S. industrial base could expand on the bottom end: essentially pushing the onshore/offshore threshold down to the point where all manufacturing, no matter how little value is added, can be effectively done in the United States. This could be accomplished, for instance, by a rigorous protectionist trade policy. It is the least desirable area of expansion for two reasons. First, the United States does not want to court or expand low-value-added jobs that do not sustain a high standard of living. If pushing down the onshore/offshore threshold means lowering the U.S. standard of living (getting American workers to accept low wages), this approach is not only unrealistic, it is undesirable. Second, innovations in manufacturing methodology and technology are changing the way manufacturers add value; low-skilled, direct-labor-intense manufacturing is a declining breed. As long as the world manufacturing base keeps shifting up the value continuum (as direct labor content shrinks), the U.S. industrial base will be effective in a broader spectrum of that continuum. U.S. workers, however, must be equipped with the skills to add value that sustains the high U.S. standard of living. Without them, U.S. manufacturing personnel will be as hard hit as their offshore counterparts as low-skill, direct-labor-intense manufacturing jobs become more and more scarce.

This analysis must not suggest, however, that the United States abandon low-value-added, direct-labor-intense manufacturing. The ability to excel in high-value-added manufacturing is linked to a strong presence on the low-end for several reasons. First, low-margin manufacturing is important because of the relative weights of different factors in COGS. For low-margin products, COGS are dominated by production costs, while high end products have a great proportion of COGS in nonproduction functions (e.g., installation, marketing, and R&D); therefore, the financial incentive to minimize production costs through manufacturing improvements is relatively insignificant. Further, the source of value in low-end manufacturing may be more in process development and the lessons taught to the total organization than in the market value of a low-margin product. The ability to innovate and speed product realization depends crucially on lessons learned through effective manufacture of high-volume products as well. Consequently, the definition of high- and low-value manufacturing from a national comparative advantage perspective needs to be reassessed.

Another reason to maintain capability in low-margin products is the relatively higher risk involved in concentrating strictly on high-margin products. Success in high-margin goods often depends on speed to market; margins decline over time as competitors enter, so rapid product realization and constant innovation are essential—and difficult. Only rarely are conditions right for such products to sustain a business.

Finally, movement of low-value but often high-volume production offshore can have a significant and detrimental effect on infrastructure. Domestic manufacturers' decisions to move offshore can devastate the local supplier base because the volume requirements of the high-value goods left in the United States cannot support the large supplier network. At the same time, the infrastructure offshore is reinforced. Eventually, this infrastructure becomes a magnet—if a firm wants to operate in a certain field, the skills, components, and materials are concentrated abroad. Malaysia's growth to dominance as a location for semiconductor assembly attests to this point.

Only methodologically advanced, well-managed firms will be able to maintain competitive high-volume operations onshore at a profit. This is another advantage of methodological excellence: it allows firms to keep low-margin product lines running profitably onshore—often essential to future success in other, higher-margin areas of manufacturing.

To summarize, U.S. corporate and government policy can expand the effective area of the U.S. industrial base in several areas. In the long-term, the most desirable areas of growth are in high-wage, high-value-added manufacturing. Having a large, fair, and diverse state-of-the-art market is essential to U.S. effectiveness in these areas. A mobile, highly skilled work force is also essential. Perhaps most important, however, is for the U.S. industrial base to mobilize its resources in an effort to add new kinds of value—to rediscover the value frontier. This means managing effectively while fully exploiting methodological, technological, and other sources of value that can shape demand in both the U.S. and export markets.

RECOMMENDATIONS

With a state-of-the-art market at home and open markets abroad, the United States will be in the best possible position to continue innovating as the world manufacturing industrial base evolves. To this end, the committee offers several recommendations for private and public action.

Firms must:

1. Accept responsibility for losses in competitiveness instead of blaming them on exogenous cost factors. Managers must understand that they have the power to stimulate dramatic improvements in manufacturing effectiveness. External cost factors need not have a significant impact—in most in-stances—on a firm's ability to produce competitively. The cost advantages of offshore locations can often be offset by strong, effective management of a skilled work force keeping appropriate manufacturing process technology in tight control.
2. Understand that global competition has raised the performance standards required for manufacturing success; thriving firms need to perform as “best-in-class” in their respective markets. To do so, firms must not let outdated notions of cost drive business decisions (i.e., focusing on labor), they must collaborate with and learn from domestic and foreign competitors, and they must educate and train managers and production workers so they can drive lean production.
3. Take advantage of natural U.S. advantages: (a) a large and relatively open market comprising innovative, creative, risk-taking manufacturers and (b) an excellent university system capable of driving tremendous intellectual advances and providing highly skilled personnel for world-class manufacturing.
4. Constantly strive to provide customers with higher value-added—embracing both technological and methodological sources of value. This means opening markets at home and abroad so that new technologies/methodologies can be accessed and R&D costs can be amortized. U.S. firms can push new-value frontiers only if they do it globally.

Government must:

1. Foster a favorable environment in the United States for competitive global manufacturers, foreign and domestic, by maintaining the macroeconomic conditions necessary to sustain a state-of-the-art market. The strong competition and healthy demand needed for such a market require stability and predictability in prices, tax regimes, and trade policies to allow confident decisions with long time horizons.
2. Avoid restrictions on foreign direct investment, joint ventures, and other sorts of interfirm cooperation or technology

flows that would inhibit U.S. manufacturers' access to skills, knowledge, and technology, whatever the source. Fight similar restrictions abroad where they limit U.S. exports, direct investment, and technology access.

3. Encourage and support work force education and skills mobility. A skilled, educated work force is a critical component of a state-of-the-art market. The United States must maintain the necessary investment in its educational infrastructure to ensure that the supply of courses, materials, and instructors is sufficient to meet demand, not just for new graduates but for much of the existing work force.
4. Resist pressures from the business community to protect the status quo. U.S.: business failures are not necessarily market failures requiring government remediation.

Given appropriate incentives, skills, resources, and management of manufacturing as an integrated system, U.S.-based production can be competitive, not only in cost but also in quality, features, and timeliness. Both American and foreign-owned companies have proven it.

NOTES

1. See Acknowledgments, p. v.

2. In 1965 Digital's site location decisions were driven mainly by a desire for access to low-cost labor. By 1985, however, the rationale for moving offshore had changed. Instead of looking for low-cost labor, Digital was siting factories in order to gain market access, to gain access to skills and technology, and to create a worldwide manufacturing network that would be less vulnerable to currency fluctuations.

3. Traditional cost accounting systems often allocate fixed costs on the basis of variable (e.g., direct labor), costs, thereby exaggerating the importance of labor costs. Alternative systems, such as activity-based costing, provide a more accurate identification of cost drivers and allocates them more effectively. For a full discussion, see Robert S. Kaplan, ed., *Measures for Manufacturing Excellence* (Boston, Mass.: Harvard Business School Press), 1990.

4. For a full elaboration of these points, along with specific examples of how different firms manage OEM relationships and other strategic alliances, see, Gary Hamel, Yves L. Doz, and C. K. Prahalad, "Collaborate with Your Competitors and Win," *Harvard Business Review*, January-February 1989, pp. 133-139.

5. Hamel, et al., op. cit.

6. It is significant, however, that as long as there is even a single environment that offers significantly lower costs (or that has a significantly lower standard of living), the onshore/offshore threshold will be upheld. Whether firms actually move offshore will be determined by their ability to rationalize costs onshore through better management or other factors such as market access or access to skills and technology.

7. Evidence of this force at work can be seen in Honda's practice of exporting U.S. production to Europe.

8. Although services are another source of value-added, they have been excluded from this discussion.

9. There is a dynamic at the frontier that tends to keep firms there. The ability of Japanese DRAM manufacturers, for instance, to make devices more efficiently than U.S. competitors gave them market share, which helped them get an adequate return on their capital and R&D investments. Access to these profits let them continue to reinvest in new generations of the device, effectively pushing them and the frontier farther out.

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Index

F

G

H

I

J

K

L

M

W