MEETING THE CHALLENGE:
U.S. INDUSTRY FACES THE 21ST CENTURY

THE U.S. AUTOMOBILE MANUFACTURING INDUSTRY

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Contents

FOREWORD

For more than a decade there has been widespread and increasing concern that the ability of the United States to achieve sustained economic growth and long-term prosperity is adversely affected by declining industrial competitiveness. Congress, in a bipartisan response, has introduced a wide range of programs and policies to improve U.S. competitiveness. Whether focused on building a 21st-century infrastructure, stimulating technological innovation and commercialization, improving the business climate for investment and growth, supporting education and training, or promoting trade, these policies start with assumptions, often implicit, about the competitive position of U.S. industry.

Meeting the Challenge: U.S. Industry Faces the 21st Century is a new series of studies, produced by the Department of Commerce's Office of Technology Policy, that assesses the competitive position of a number of major U.S. industries and the factors influencing their growth. Drawing principally from the experience and insight of the private sector, some 150 experts from over 30 organizations in industry, academia, and government have contributed to the drafting and review of the studies. Overall, the studies provide a framework for public policy that is better informed and that more accurately reflects the shifting, and often improving, competitive position of U.S. industry.

This report on the U.S. automobile manufacturing industry concentrates on the Big 3 firms (Chrysler, Ford, and General Motors) and discusses the condition of the industry, product and production strategies, the importance of the supply chain, distribution and retailing, and conclusions and possible future directions. It suggests that, although the U.S. industry (and the Big 3 in particular) has made tremendous progress in the past 15 years, new challenges are clear as the global market, technology, and industry structure continue to evolve. For example, the fastest growing markets are in countries that are developing an auto industry of their own. And as the report makes clear, best practice is easily transferred to emerging producers. New technologies are also being introduced, often in response to the challenges posed by environmental and safety regulations. In addition, the major producers are experiencing structural pressures as suppliers produce a larger fraction of the finished product's value, and well-financed and independent organizations threaten the traditional distribution networks on which producers rely to sell their products.

Graham R. Mitchell
Assistant Secretary of Commerce for Technology Policy

ACKNOWLEDGMENTS

MIT's International Motor Vehicle Program (IMVP) was asked to develop this study in parallel with industry reports in other sectors to provide strategic assessments of key U.S. industries to government policymakers. Drawing on the experience and expertise of several dozen IMVP-affiliated researchers from around the world and numerous industry participants, this study reports on the U.S. automotive industry in the context of the world automotive industry.

The study represents contributions from Martin Anderson, Erik Brynjolfsson, Joel Clark, Michael Cusumano, John Ehrenfeld, Frank Field III, Kaye Husbands, Jacqueline Isaacs, Thomas Kochan, James Maxwell, Jennifer Nash, Kenneth Oye, Daniel Roos, Richard Roth, Sandra Rothenberg, Brian Schenck, Gregory Scott, and Daniel Whitney (Massachusetts Institute of Technology); Kim Clark (Harvard Business School); Takahiro Fujimoto (University of Tokyo); Young-suk Hyun (Han Nam University, Korea); John Paul MacDuffie, Jeffrey Dyer, David Ellison, and Frits Pil (Wharton School of Business, University of Pennsylvania); Susan Helper (Case Western Reserve University); and Mari Sako (London School of Economics and Politics).

In addition to the IMVP staff listed above, John Lafrance and Don Hillebrand of the Department of Commerce, Technology Administration, contributed to the study.

Executive Summary

The Automotive Industry Today: A Global Endeavor

While sometimes characterized as "mature," the U.S. automotive industry continues to experience dynamic change—change that sweeps across national borders. To succeed, auto manufacturers must manage large and complex supply chains, spanning many geographic regions, and pursue opportunities in diverse national markets. While national policies play an important role in shaping the environment for local manufacturing operations and resulting products, cost competition increasingly drives the industry toward global product offerings.

This report explores several important dimensions of the forces of change facing the industry and reviews the responses of the Big 3 manufacturers (Chrysler, Ford, and General Motors) to those forces.

Forces of Change in the U.S. Market

Important changes are under way in the U.S. market, both in the type of vehicles preferred by consumers and in the system that delivers those vehicles to consumers. Equally important, foreign firms are opening new assembly plants in the United States, and foreign suppliers of parts and components are building a domestic presence.

In response to shifting consumer preferences, the variety of products supplied by the automotive industry has increased dramatically. Lifestyles have shifted toward the two-wage-earner family, and as a result, demand for light utility vehicles has surged. In addition, consumers have shown increasing interest in both safety and performance. At the same time, average new-vehicle transaction prices have continued to rise at a rate far higher than the increase in average household income, posing a serious challenge for the industry.

Dramatic change is also taking place in the "downstream" activities of the automotive industry—distribution and retailing. These activities represent 20 to 30 percent of the value of a new vehicle and are an important potential source of cost savings. The changes in this area reflect a shift from capital-intensive operations (involving inventory investment) to information-intensive operations (providing the right vehicle in the right place at the right time). This shift is leading to the development of flexible and highly entrepreneurial structures and methods to serve customers.

Finally, new assembly plants operated by Japanese and German auto manufacturers have been built in the United States, introducing additional competitive challenges for the Big 3. Because of their location, they have also altered the regional distribution of automotive employment. These new "transplant" manufacturing facilities have been accompanied by the arrival of new suppliers from the home markets of these manufacturers. The presence of these new suppliers has benefited both the new assemblers and the Big 3 by introducing additional competition into the supply of automotive parts.

Competitive Responses of Big 3 Manufacturers

The Big 3 have responded to these forces of change in a variety of ways. Most important, they have dramatically improved both the quality of their products and the productivity of their operations. This study shows that Big 3 plants improved their productivity from 24.1 to 20.7 direct labor hours per vehicle between 1989 and 1994—a 17 percent improvement. While Japanese-owned plants in Japan improved more slowly, they still remain the most efficient producers—but by a relatively smaller margin.

From a broader perspective, the productivity data underline the need for continuous improvement in these areas, evidencing the convergence of average performance across the world. European plants improved their productivity nearly 30 percent, and new entrant countries (Korea and Mexico) showed significant improvement as well. Equally important, the data show that productivity varied widely within each regional group, suggesting a disparity among regional competitors in the management of vehicle production.

The Big 3 have recognized that the development of new products is of special importance as manufacturers struggle to respond to the demand for product variety and low prices. Since the 1980s, these companies have shortened the time required to bring a new product to market and decreased the engineering effort required for new products. The large differences among the three companies in their approach to this challenge—in terms of the involvement of suppliers, organizational structures, and the degree of coordination among different product offerings—are explored in this study.

Human resource practices represent another important determinant of the auto industry's competitiveness. There appears to be wide variance among U.S. manufacturers in this area—ranging from traditional labor-management practices to new and unique management structures. The rate of diffusion of new practices within the United States is slow, but research presented here suggests that several important changes are occurring: (1) decreases in inventory buffers; (2) increases in the use of teams, job rotation, and worker suggestion programs; and (3) use of contingent compensation, training investment, and other human resource practices.

A final area of competitive response in which each of the Big 3 is developing its own unique approach is the management of supply chains. Earlier research suggested that management of automotive supply chains was improved by the development of close relationships among auto manufacturers and suppliers who develop and produce components and subsystems. Recent events suggest a number of key issues in the management of these relationships. The nature of the relationship may vary with the supplier's degree of involvement in the development of parts for the manufacturer. Each of the Big 3 companies is pursuing a different approach in this area based on its corporate experience and strengths.

INTRODUCTION

This report discusses the U.S. automotive manufacturing industry in the context of the world industry. The first section discusses the status of the U.S. automobile manufacturing industry, concentrating on the performance of the Big 3. Then market forces and production trends in the industry are addressed, focusing primarily on the geography of automotive production. The next section reports on competitiveness and product strategy, particularly in the areas of automotive manufacturing and product development, the two areas where the best data are available. The following section highlights technical areas where improvements and innovations are needed to make the next generation of vehicles possible. The dynamics of the adoption and evolution of lean production practices are then discussed. Two sections address supply chain issues looking upstream of the manufacturing plant, as well as downstream from the manufacturing plant to automobile distribution and retailing. A final discussion covers several “social agenda” issues such as mobility, environment, and safety. The last section provides the report’s conclusions.

STATUS OF THE INDUSTRY

Like a number of long-established U.S. industries, the automobile manufacturing industry has gone through wrenching times in the past 10 to 15 years. Nevertheless, the U.S. industry is still home to the two largest vehicle manufacturers in the world, General Motors and Ford (table 1), and has been responsible for 20 to 25 percent of world vehicle production in several years since 1980 (figure 1).

Over the past few years, the United States has closed the gap with Japan with respect to the volume of domestically produced passenger cars (figure 2) and overtaken Japan in the increasingly important sector of Trucks, Buses, and Others (figure 3). In this sector, which includes the popular light trucks, minivans, and utility vehicles, U.S. producers are considered market leaders.

The U.S. Big 3 have recently gained market share in domestic passenger car sales (figure 4), from 61 percent in 1991 to 64 percent in 1994. Transplants have also increased their share, from 14 percent in 1991 to 17 percent in 1994. Despite these gains—which were made at the expense of imports—the United States is running a well-publicized trade deficit of $50 billion (as of 1994) in the motor vehicle sector. The $89 billion of production by foreign affiliates of the Big 3 (figure 5) is less well known, and although it does not solve the trade deficit problem, it does put the U.S. industry's position in the world in perspective.

The U.S. Big 3 have recently gained market share in domestic passenger car sales.

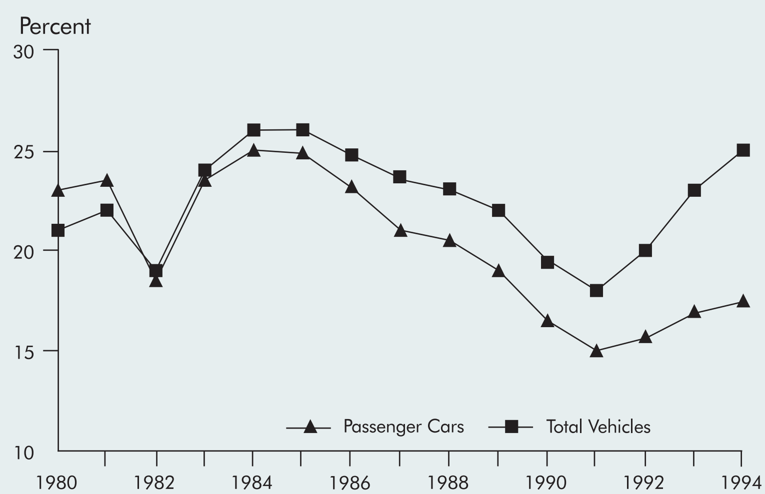
Through the past 15 years, the Big 3 have maintained the confidence of financial markets—their market capitalization has kept pace with the capitalization of Standard & Poor's Industrials (figure 6). Over the years, the return on assets of the Big 3 has generally been below par (figure 7) in spite of their efforts to increase profitability and efficiency. One of the casualties of these efforts has been employment, which has decreased substantially since the late 1980s (figure 8).

Table 1. 1994 Vehicle Production (in Thousands)

Company	Country	Passenger Cars	Light Trucks and Commercial Vehicles	Total
General Motors	U.S.	2,604	1,845	4,450
Ford	U.S.	1,661	2,073	3,734
Toyota	Japan	2,769	739	3,508
Peugeot-Citroën	France	1,770	121	1,892
Chrysler	U.S.	551	1,142	1,693
Renault	France	1,395	261	1,656
Nissan	Japan	1,341	268	1,609
Volkswagen/Audi	Germany	1,516	85	1,601
Fiat	Italy	1,231	127	1,358
Mitsubishi	Japan	891	414	1,306

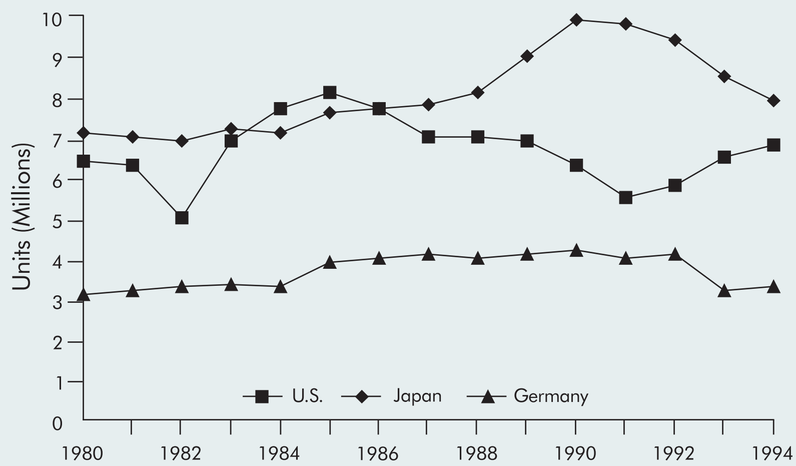
Source: American Automobile Manufacturers Association
Note: Numbers may not add to totals due to rounding.

Figure 1. U.S. Domestic Production as a Percentage of World Production



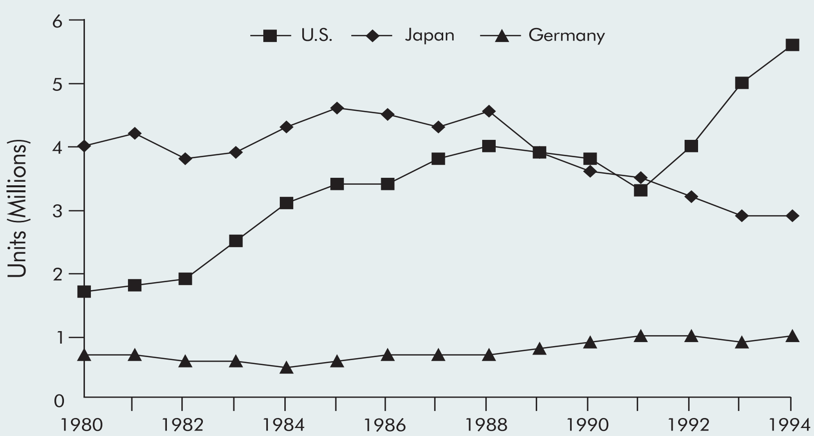
Source: American Automobile Manufacturers Association.

Figure 2. Domestic Production of Passenger Cars in the U.S., Japan, and Germany



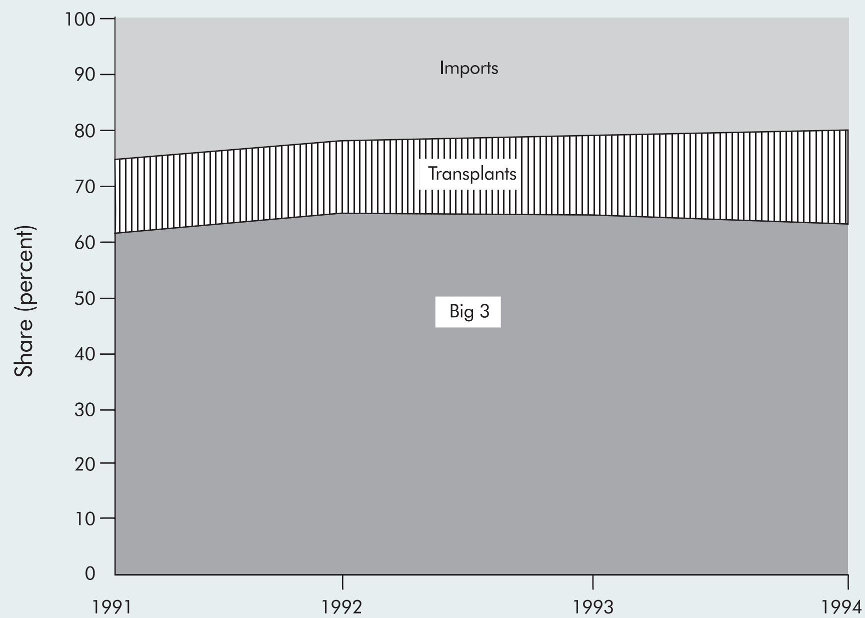
Source: American Automobile Manufacturers Association.

Figure 3. Domestic Production of Trucks, Buses, and Others in the U.S., Japan, and Germany



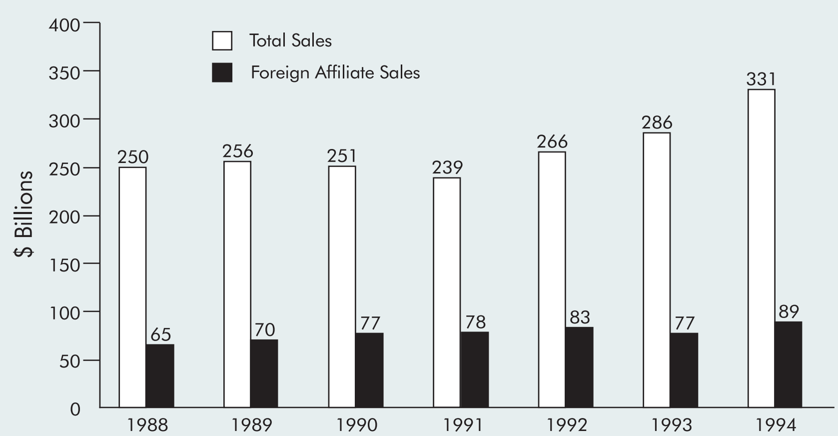
Source: American Automobile Manufacturers Association.

Figure 4. U.S. Passenger Car Sales as a Percentage of Market Share



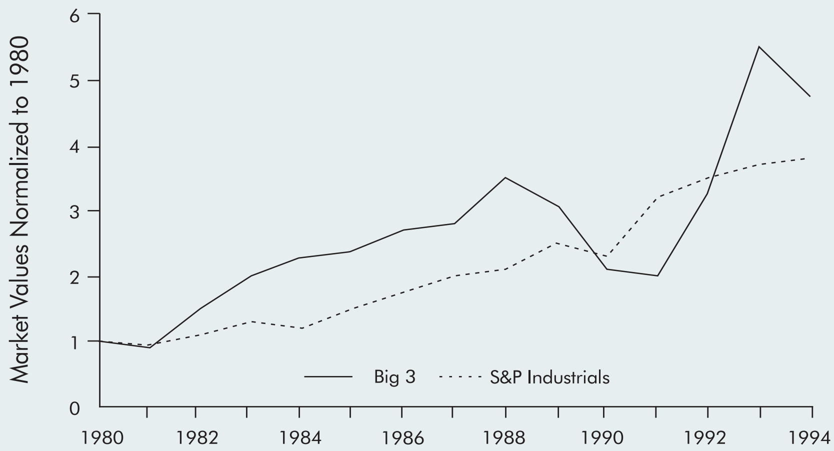
Source: American Automobile Manufacturers Association.

Figure 5. Big 3 Sales



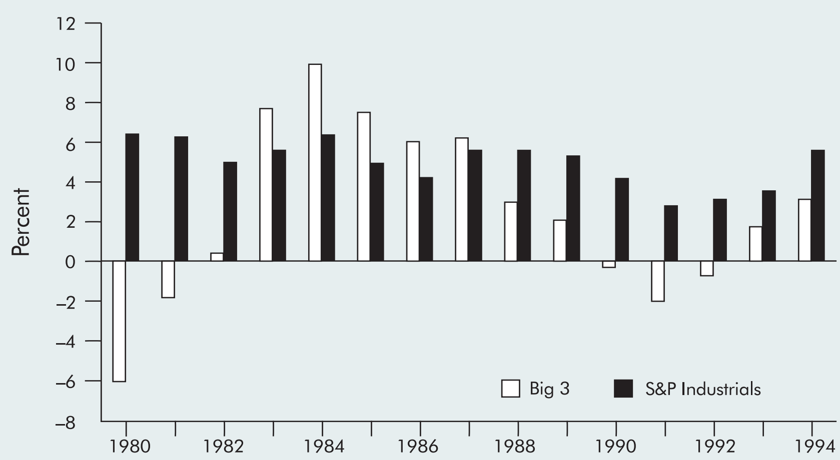
Source: Compustat.

Figure 6. Normalized Market Values for the Big 3 and S&P Industrials



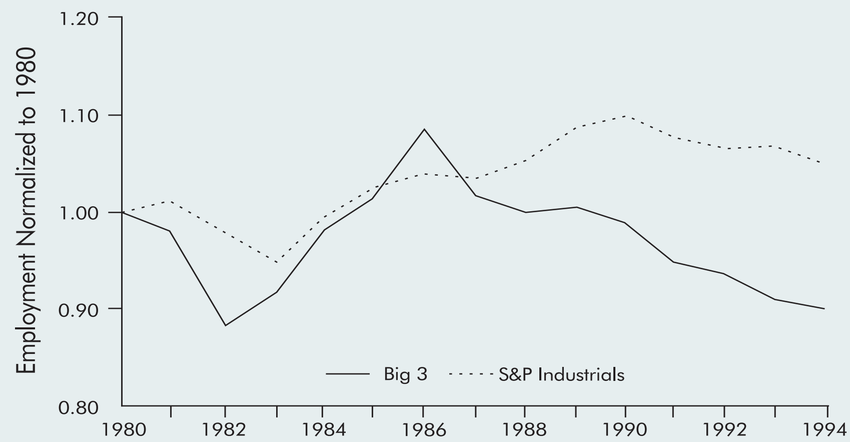
Source: Compustat.

Figure 7. Return on Assets



Source: Compustat.

Figure 8. Normalized Employment



Source: Compustat.

MARKET FORCES AND PRODUCTION TRENDS

U.S. Market Trends

The variety of motor vehicles is expanding and the market is no longer dominated by a handful of very high volume cars. Detroit automakers have been able to respond much more quickly to this demand for a range of models with the adoption of lean production. The average time to market or "lead time" of U.S. automakers has fallen from about 61 months to about 52 months—below the Japanese average, which actually increased from 45 to 55 months from the late 1980s to the early 1990s. As a result, U.S. companies can now compete with the Japanese in product development. Lead time may already be significantly faster at Chrysler than at many of the Japanese companies. However, American manufacturers' competitive disadvantage in model mix complexity creates a barrier to their ability to compete in product diversity.

U.S. companies can now compete with the Japanese in product development.

The continuous rise in price of new cars is an ominous trend for all automakers. According to the National Automobile Dealers Association, the average new-vehicle transaction price has soared from $8,850 to $19,200 since 1981. Median U.S. household income, however, has increased from $22,400 to only $37,800. Therefore, car buyers now pay a higher percentage of their annual income to purchase new cars. The increasing costs are forcing consumers into alternative buying and replacement strategies—retaining cars longer and purchasing used cars instead of new cars.

American family lifestyles have also changed. There are more working women, which has changed commuting and errand-driving patterns. Families once had a commuting car for the wage earner and a larger car for family use. Often now they have two wage earners instead of one, and the second family vehicle is a minivan or utility vehicle to supplement the family car. U.S. automakers have been very effective in creating and supplying this new market, excelling in minivans, light trucks, and recreational vehicles.

Light trucks are not only popular in the American automotive market, but also highly profitable for Detroit's automakers. They are relatively inexpensive to build, and their price has been high due to customer demand and relatively few viable Japanese competitors. Light trucks are predominantly a U.S. market and have captured nearly 50 percent of the entire U.S. automotive market.

Another trend influencing the automotive industry is consumer preference for certain features. Consumers are choosing safety (e.g., airbags, antilock brake systems) with amenities (e.g., air conditioners, powerful engines, power steering, and compact disc players) over vehicles whose primary appeal is size and interior space. Factors influencing customer choices are performance, suitability to personal needs, and family lifestyle, safety, comfort, and appearance. Consumers are showing a taste for the practical, as embodied in the Toyota Camry and the Ford Taurus, both top sellers in the medium price range. Japanese automakers, however, have increased market share in the United States through new "luxury" nameplates: Lexus, Infiniti, and Acura. In addition, previously "compact" models such as Toyota's Camry and Honda's Accord have become larger and more luxurious.

The Geography of Production: Global Sourcing and Factory Transplants

In automotive development and manufacturing, geography plays a major role.

In automotive development and manufacturing, geography plays a major role. Historically, automotive employment has been tightly clustered, with major concentrations in Nagoya, Detroit, and Stuttgart, for example. In more recently developed infrastructures, we also observe very tight clustering—in the midwestern United States, we see a tight concentration of the Japanese assembly transplants and transplant suppliers.[1] In the new transplant clusters, the philosophy of just-in-time (JIT) seems to play an important role in location decisions: All of the suppliers want to be near their assembler customers to achieve short, fast supply lines—just like in Toyota City.

We also see recent trends of "de-clustering," however. In search of cheaper or different labor forces, manufacturers from Europe, North America, and Japan have all built plants in Mexico. Thailand, Spain, and Eastern Europe—each quite distant from a historical automotive cluster—have attracted significant investment as well. Toyota even built a major plant in Kyushu, Japan, several hundred kilometers south of Toyota City, in search of an expanded labor base. These patterns raise a puzzle for analysts. In particular, why did JIT supply lines matter before and not now? Has a critical level of learning transpired such that geographic closeness is no longer important? Are only the suppliers of noncritical components moving south? If so, what defines criticality for geographic closeness?

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[1] Richard Florida and Martin Kenney, "The Globalization of Japanese R&D: The Economic Geography of Japanese R&D Investment in the United States," *Economic Geography* 70, no. 4 (1994).

Furthermore, if network clustering is important, as the Florida-Kenney work on the midwest auto industry suggests, then one might have expected the North American Free Trade Agreement (NAFTA) to reduce the incentive to build cars or parts in Mexico, since free trade guarantees that companies can eventually ship south as much as they want. However, it is not clear what role, if any, network clustering has played in post-NAFTA decisions concerning plant location. What new light does this fact shed on the importance of the network clustering?

All of these questions are critical to regional economic development. If attracting a manufacturing plant guarantees that a swarm of suppliers will follow, then it may pay for states to offer incentives to attract the manufacturing plants, as many states have done. On the other hand, if suppliers chase low wages, other government strategies make sense. If some suppliers go toward low wages and others must be close to the manufacturers, then governments must consider what mix of companies they should try to attract or should reasonably hope to attract.

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In Korea, India, Eastern Europe, Thailand, Brazil, and many other developing countries, the growth rate of automotive sales now far outpaces those of the traditional automotive manufacturing and consuming areas of Western Europe, North America, and Japan. Furthermore, these developing countries typically want to fill domestic demand with domestic production, driving multinational automobile firms and suppliers to develop local manufacturing capabilities to serve local markets. Following the policies that these governments pursue and watching how automobile and supplier companies respond to these government initiatives will be informative for U.S. policy makers, who may also be concerned with automotive employment shifts.

Foreign Transplants in the United States

The combination of high national productivity and the relative decrease in value of the dollar against the yen and the deutsche mark has made the United States a more attractive manufacturing site for foreign automakers. This development has provided a new source of investment, jobs, and training for Americans. Moreover, the transplant assemblers are significantly influencing the U.S. automotive supply base, both by encouraging traditional Japanese and German suppliers to set up transplant operations and by inciting the traditional U.S. suppliers to become more competitive. These improvements to the supply base, driven in part by the Japanese transplants, in turn benefit the Big 3.

The transplants represent an enormous positive economic impact for the United States, compared with having that many vehicles imported from Japan, for example.

The Japanese-transplant assemblers in North America have continued to expand their production and are now approaching a volume of three million cars and light trucks per year (up from two million units in 1991). The transplants represent an enormous positive economic impact for the United States, compared with having that many vehicles imported from Japan, for example. These investments have helped the Japanese companies as well, which would be in far deeper trouble had they not diversified their manufacturing base outside the high-priced labor and parts markets in Japan. The displacement of Big 3 employment and production with transplant production is more difficult to assess. In the main, it has decreased the financial and market dominance of the Big 3, although none are currently threatened with survival concerns. It has also affected the geography of automotive employment within the United States.

Investment in Developing Countries

In the foreseeable future, most automotive demand in the United States, Japan, and Western Europe will be for replacement vehicles. Demand will be flat or grow slowly. In the developing world, however, demand is skyrocketing, and many governments are requiring the establishment of domestic production to satisfy this demand. As a result, the world's major multinational auto companies are pouring significant fractions of their investment funds into capacity in China, India, South America, and Southeast Asia. For example, Ford is spending approximately $1 billion to set up factories in China and Southeast Asia. General Motors (GM) has invested heavily in building up China's part-making facilities. Last fall, GM pledged a fresh $130 million for three parts facilities in Shanghai. Overall, GM has agreed to set up 25 components-making ventures valued in hundreds of millions of dollars in China. GM also has been chosen to participate in a $1 billion deal to make luxury cars in China and has announced a $1 billion assembly plant investment in Thailand.

In Southeast Asia, the Japanese have a huge lead and are likely to continue dominating that market. India and China are still wide open, with GM, Chrysler, Peugeot-Citroën (PSA), Isuzu, and Volkswagen having early status in China. The Europeans and Americans are probably stronger in Latin America than the Japanese. All of these markets are in early stages of development, however, and significant change should be expected. All of the major players seem to be seeking to craft a global strategy aimed at the developing world, and these areas will be critical battlegrounds in the coming decade.

Competitiveness and Product Strategy

One of the most critical issues for the automotive industry today is competitiveness in cost, quality, and product offerings. Companies cannot survive in today's market if they neglect any of these areas. In *The Machine That Changed the World*, published in 1990, the International Motor Vehicle Program (IMVP) documented significant differences in these areas between the best- and worst-performing plants and companies. Since that time, differences between the United States and Japan in productivity and quality have shrunk and effectively disappeared in new product development lead time, pointing to a dramatic overall improvement in the competitive position of the Big 3 firms.

Manufacturing Plant Performance

The automobile is one of the most complex consumer products in existence. The automotive manufacturing process serves as the "moment of truth" for the entire design, development, supply chain, and manufacturing process. If the parts do not fit when the manufacturer attempts to put them together, the system has a defect that must be tracked down and eliminated. Thus, auto companies focus a great deal of attention on understanding and improving the manufacturing process.

The automobile is one of the most complex consumer products in existence.

Across the world auto industry, the differences in regional averages in quality, productivity, and diversity are declining. Within regions, however, the variance in performance is high, with large gaps between the best and worst plants. Below, we report highlights from the assembly plant performance research, both from the study of 1989 (Round 1) and from the recent replication and expansion of the analysis with 1994 data (Round 2).

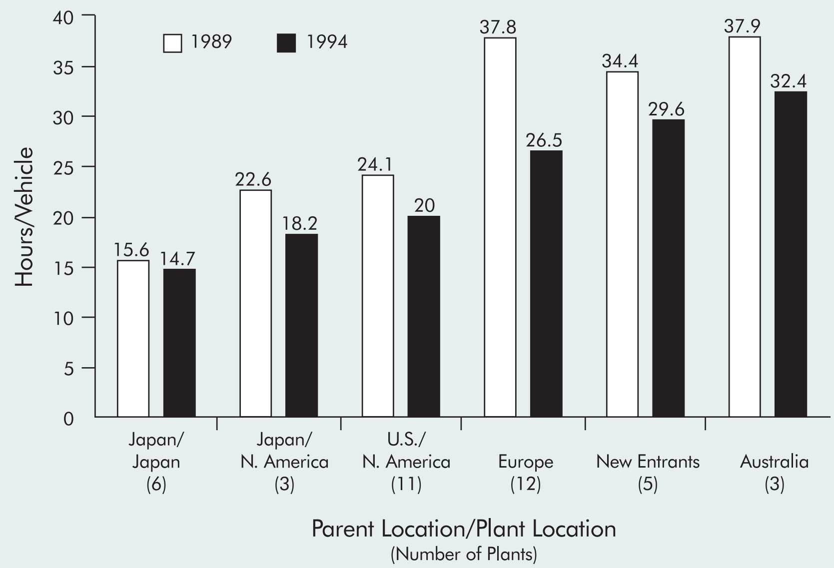
Productivity Performance

In 1986, the IMVP developed an innovative methodology for normalizing differences in vehicle designs and plant practices to enhance comparison of productivity among plants making different vehicles with a variety of manufacturing practices and methods. This methodology has been improved in the 1990s and, we believe, allows reasonable comparisons across disparate plants and vehicles.

Due to widespread improvement in North American manufacturing plants, the performance gap between average U.S. and Japanese plants has narrowed considerably.

Due to widespread improvement in North American manufacturing plants, the performance gap between average U.S. and Japanese plants has narrowed considerably. Big 3 plants are not the only ones that have improved over this period. Korean plants and Japanese plants in North America have shown considerable gains. European plants have shown

Figure 9. Scale = Weighted Productivity Averages for Matched Sample of Plants, 1989 and 1994



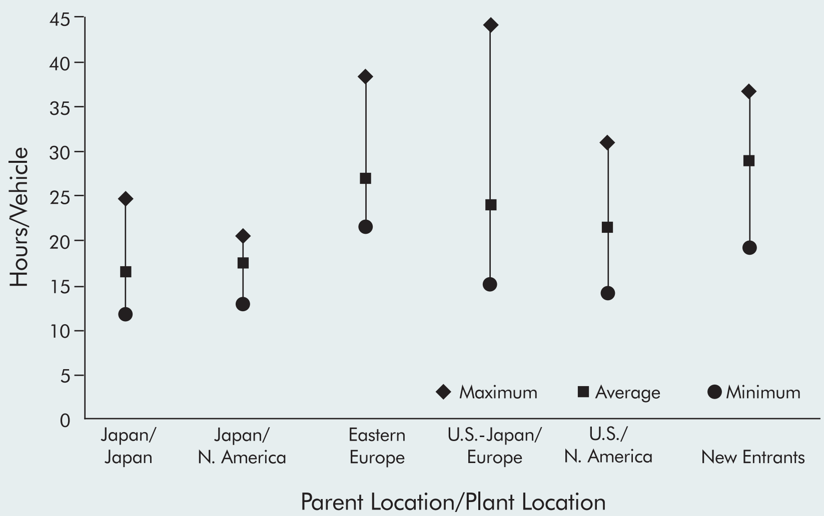
Source: Copyright 1996, MacDuffie & Pil. All rights reserved.

the greatest percentage improvement in productivity of any region, partly because of a strong push toward adoption of lean production and partly because they had lagged so far behind the Japanese and North American plants.

Figures 9 through 13 depict international productivity trends from 1989 to 1994. The full 1989 sample comprises 62 plants from 24 companies and 20 countries, while the full 1994 sample comprises 75 plants from 20 companies and 20 countries.

Figure 9 shows that the U.S.-owned (Big 3) plants in North America (both United States and Canada) improved their productivity by 17 percent—from 24.1 to 20 hours per vehicle. In comparison, Japanese-owned plants in Japan showed only a 5.8 percent improvement over this period, from 15.6 to 14.7 hours per vehicle. However, the relatively low percentage improvement of the Japanese plants cannot be construed too negatively. The Japanese still produce cars faster than any other manufacturer, and on average they assemble a car over five hours faster than the Big 3 (i.e., in 25 percent less time). In addition, these averages mask far greater gains achieved by some Japanese plants, such as Toyota's RAV4 line in Motomachi.

Figure 10. Productivity Performance within Regional Group, 1994



Improvements for groups of plants other than the Big 3 were also impressive. European plants made a nearly 30 percent gain in productivity, dropping their hours per vehicle from 37.8 to 26.5—about where the U.S. automakers were five years ago. Among the plants in new entrant countries (mostly in Korea but also in Mexico, Taiwan, and Brazil), productivity increased by nearly 14 percent, from 34.4 to 29.6 hours per vehicle—not far behind the current European average. Japanese-owned plants in North America, the "transplants," improved their productivity by 19.5 percent.

Improvements for groups of plants other than the Big 3 were also impressive.

The regional averages above conceal considerable variation in productivity across plants within each region. Figure 10 reveals the extent of this variation, showing the average, minimum, and maximum hours per vehicle for plants in each region. The range is quite large in some regions—the best plant in Japan is more than twice as productive as the worst plant, and the same is true among Big 3 plants. This fact suggests major differences across plants within these countries. Indeed, differences in company-level capabilities are likely to be far more significant for productivity than country differences. Thus Europe's wide range of productivity performance may reflect its range of company capabilities more than its country differences. The smallest range is found among the

Much of the quality gap between Japanese companies and their American and European competitors has been closed.

Japanese transplants, which may reflect their common status as greenfield plants adjusting to the U.S. context.

Quality Performance

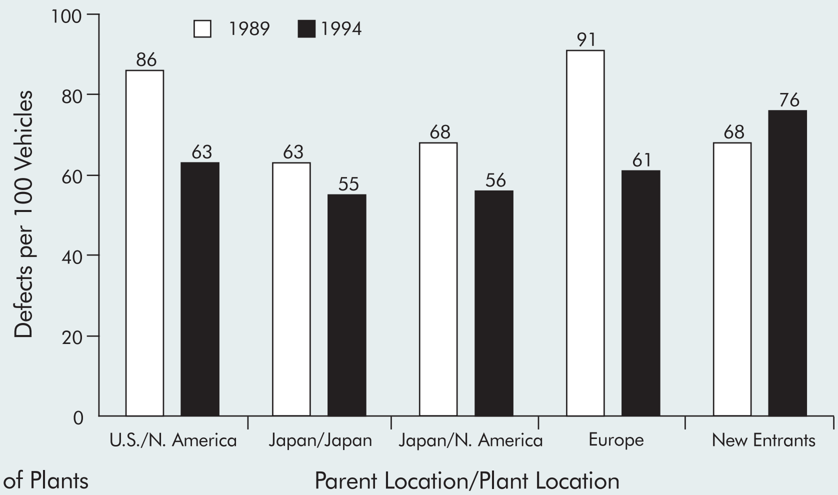
Quality performance trends are similar to those for productivity. Much of the quality gap between Japanese companies and their American and European competitors has been closed. However, the variation among plants in each regional group is large. (At this point, all quality data refer only to vehicles sold in the United States. No comparable data exist for vehicles sold in other regions.)

The dominant trend in figure 11 is convergence toward a quality level of 60 defects per 100 vehicles, with the exception of the new entrant group of plants whose quality worsened over this period. The greatest improvement is shown by European plants (33 percent) and by Big 3 plants in North America (26.7 percent). While this improvement closed much of the quality gap with Japanese competitors, Japanese plants improved in Japan (13 percent fewer defects) and in North America (18 percent fewer defects) during this period. The North American transplants have eliminated any gap in quality performance with their sister plants in Japan.

The other notable trend is the worsening quality at the new entrant plants. From 1989 to 1991, defects increased nearly 50 percent, primarily because of a period of labor conflict in the Korean industry following national political changes. The Korean automakers are already showing signs of returning to more competitive levels of quality, although they still lag behind the other regional groups.

Figure 12 shows the range of quality within each region. Here the range of performance within regions is even greater than for productivity. A wide range exists for the Japanese companies in Japan, with a threefold difference in the number of defects per 100 vehicles between the best and worst plants. While the best Japanese companies have grown stronger in terms of quality performance, the pressures of the extended recession on the Japanese industry are reflected in quality problems for the weaker companies. The range in quality performance is also quite wide for the Big 3 plants in North America, with a nearly three-to-one differential in defects between the worst and best plants. While some of this variation is specific to certain types of products (e.g., sports cars tend to have the highest number of reported defects), overall it reflects persistent differences in plant capabilities for achieving quality. The narrowest range in performance for quality is for the European plants.

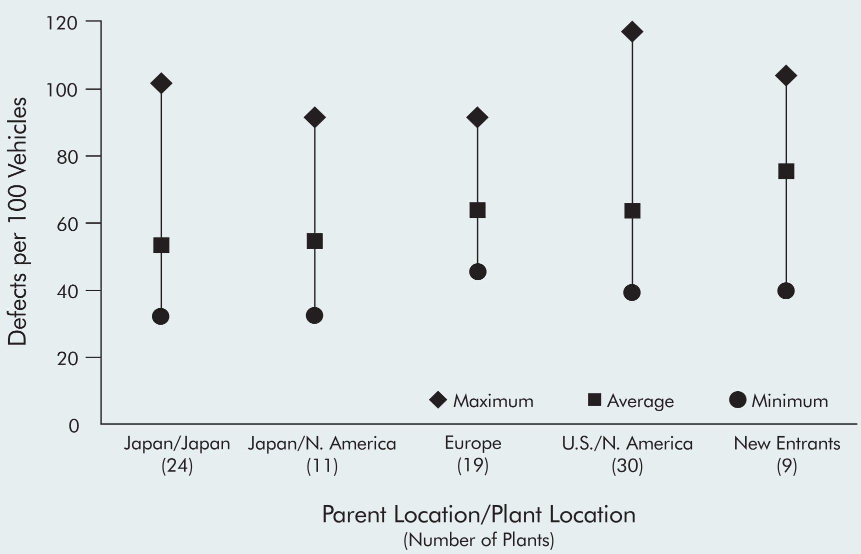
Figure 11. Quality Levels across Regions, 1989 and 1994



Number of Plants	U.S./N. America	Japan/Japan	Japan/N. America	Europe	New Entrants
1989	42	18	7	23	4
1994	32	23	12	19	6

Source: Based on data from J.D. Power Initial Quality Survey, adjusted by IMVP to reflect only assembly plant problems.

Figure 12. Range of Quality Performance within Regions, 1994



Source: Data from 1993 J.D. Power Initial Quality Survey, adjusted to reflect only assembly-related problems.

Plants that improve quality through inspection will not only incur higher costs but will also have less long-term continuous improvement in quality than those that eliminate the sources of problems.

Flexibility enables plants to respond more effectively to changes in their competitive environment.

The divergence in quality performance reflected at the regional level may also reflect differences in company strategies for achieving quality. Some plants and companies, in the United States and elsewhere, have boosted quality through additional expenditures on post-process inspection and repair; others have been more successful at building it right the first time. Plants that improve quality through inspection will not only incur higher costs but will also have less long-term continuous improvement in quality than those that eliminate the sources of problems.

Making Multiple Product Lines in a Single Plant

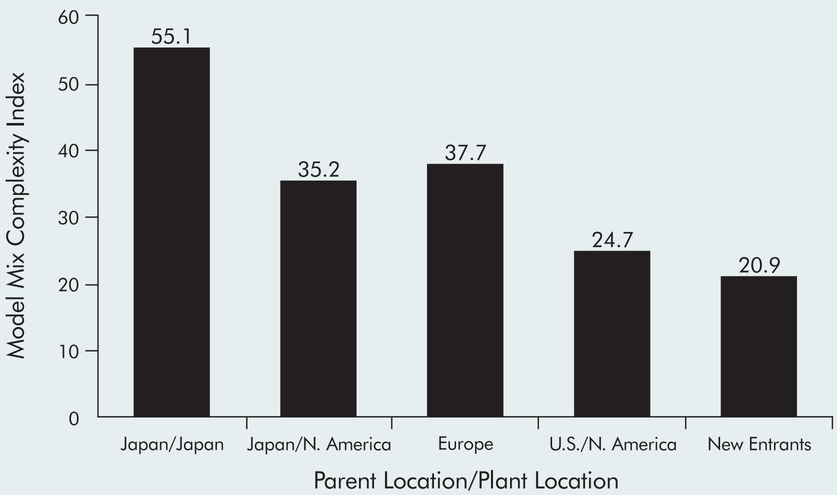
The strategic advantages of manufacturing flexibility (the ability to assemble multiple product lines in a single plant) have been widely discussed over the past decade. Companies that are able to produce a variety of products in their manufacturing plants have a number of advantages. Such plants are an important resource for a company with a product development strategy of high variety. In addition, flexibility enables plants to respond more effectively to changes in their competitive environment.

The manufacturing plants with the highest levels of product variety have typically been those that produce many different models for export—Japanese plants in Japan and European plants. Big 3 plants in North America have typically been dedicated to one or a few models. The Japanese transplants started their operations in North America with low product variety while they established their production system philosophy and have slowly increased variety over time.

Figure 13 shows the regional averages in the IMVP's International Assembly Plant Study, Round 2, for product variety (model mix complexity) based on the number of different platforms (e.g., the core design, comprising a common chassis and wheelbase), different models (e.g., Ford Taurus, Mercury Sable), and different body styles (e.g., two-door, four-door) built in a given plant. Model mix complexity is quite high for Japanese plants in Japan, with the next highest complexity level among plants in Europe and the Japanese transplants. Big 3 plants in North America and new entrant plants have lower levels of product variety.

Japanese plants in Japan, which are highest in both quality and productivity, are also highest in flexibility. These data reinforce the earlier finding that the firms need not choose among these objectives, but can instead find strategies whereby the objectives are mutually reinforcing.

Figure 13. Model Mix Complexity, 1994



Note: These are relative figures where 0 was least complex plant in 1994 and 100 is most complex.
Source: Copyright 1996, MacDuffie & Pil. All rights reserved.

Summary on Manufacturing Plant Performance

Japanese plants are still the best at automotive manufacturing by our evaluation standards. However, the gaps are rapidly closing, and the rising yen has eliminated any cost advantages that Japan once had. Like many others, the manufacturing segment of the business has become increasingly competitive. No firm can relax its efforts for continual and significant improvement.

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Product Development Performance

Automakers continually face the challenge to create "best in class" vehicles and maintain a corporate reputation for performance and value. To achieve this goal, they must be adept at managing the development process, including involving suppliers as design partners. Product development includes understanding customer needs and desires; translating those needs into "key characteristics"; developing the concepts, systems, components, and tools to deliver those key characteristics; and designing the immense logistical systems required to deliver vehicles in quantity at competitive cost and quality.

Over the past decade, U.S. automakers have popularized the minivan and sport utility/light truck vehicle classes. Continued success will result from attention to demographic trends, customer tastes, design innovation, and transportation needs. American automakers must maintain the simultaneous abilities to advance the state of the design art, respond to new or latent purchaser demands, and continually refine existing vehicle types.

Automotive firms continually explore better ways to organize themselves to perform these challenging product development functions. This section describes some of those organizational strategies as well as performance outcomes.

Alternate Development Structures

Four patterns or strategies of vehicle development management practice are described below: functional management; single-car project management; multiproject management; and multifirm, multiproject management.

Functional management is characterized by teams of specialists within largely independent and isolated technical and business areas following sequential development phases to create a new product.

Multifirm, multiproject management requires the complicated act of juggling component sharing arrangements, joint project ventures, and agreements to market cars under each other's brand names.

Single-car project management is the use of overlapped, integrated functions and program phases to improve communication and lessen the amount of change and re-work caused by changed or incompatible design priorities. Typically, this management structure is associated with a project manager who has significant authority and responsibility over the entire team developing the vehicle.

Multiproject-management attempts to leverage the advantages of single project management on multiple projects. Firms develop a portfolio of vehicle products with common features or a related design. Various products are related in terms of platform architecture, component families, and development lineage.

Multifirm, multiproject management, under which a firm integrates its development and operational activities with those of other firms, is the most difficult and demanding product management strategy. Multifirm, multiproject management requires the complicated act of juggling component sharing arrangements, joint project ventures, and agreements to market cars under each other's brand names.

To support multiproject management, the basic design of one vehicle platform is often leveraged for another through the process of "rapid design transfer," in which major structures or assemblies are reused in follow-on projects. The benefits of such practices are greater product variety, lower average design age throughout the corporate vehicle portfolio, more efficient use of development resources, and a higher level of component commonality. The difficulties include cross-project coordination and design compromises that yield multiproduct savings but distinct vehicles. A number of firms have installed a heavyweight coordinator who serves as the executive manager over a set of projects in order to address the delicate balance between individual projects and linked platforms.

Product Development Performance Metrics

The research team of Ellison, Clark, Fujimoto, and Hyun[2] has developed a rich database to examine product development performance over the past decade. In comparing new product development practices in the United States, Europe, Japan, and Korea, they have collected data on two key measures of performance for automotive product development projects: total engineering hours devoted to the development project and total months of lead time from concept to market for new vehicle projects.

The metrics calculated from the raw data are adjusted for factors such as product complexity, new parts content, and supplier development content in an attempt to approximate an "apples to apples" comparison. In table 2, these performance measures are grouped and averaged by geographic location of the corporate owners of the developing company. The data are based on a sample of 29 new car projects developed in the 1980s and 27 different new car projects in the 1990s. The results show that U.S. and European firms have made significant gains, catching up completely with the Japanese in lead time but still trailing in the total number of engineering hours required to develop a new vehicle.

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Ellison et al. also observe a continuing shift toward "heavier" project management systems, in which the functional and technical organizations have relatively less power in the matrix management structure than the car project team leaders. This practice was described in earlier work by Clark and Fujimoto as being significantly associated with superior performance.[3] The use of suppliers in the development process, another practice associated with superior performance, has increased in the past decade.

[2] David J. Ellison, Kim B. Clark, Takahiro Fujimoto, and Young-suk Hyun, "Product Development Performance in the Auto Industry: 1990s Update" (paper presented at the IMVP Research Briefing Meeting, June 1995).

[3] Kim B. Clark and Takahiro Fujimoto, "Heavyweight Product Managers," *McKinsey Quarterly* no. 1 (1991): 42–60.

Table 2. Product Development Performance by Region

	U.S.	Japan	Europe	Korea
Engineering Hours (Millions)				
1980s	3.366	1.703	2.915	N/A
1990s	2.297	2.093	2.777	2.127
Project Lead Time (Months)				
1980s	60.9	44.6	59.2	N/A
1990s	51.6	54.5	56.1	54.5

Note: N/A = not available.

U.S. gains in performance result from fundamental changes in the way projects are managed, including more inter-disciplinary participation by more closely linked development teams, greater and more effective use of information technology, and greater delegation of project responsibility by corporate management.

U.S. gains in performance result from fundamental changes in the way projects are managed, including more interdisciplinary participation by more closely linked development teams, greater and more effective use of information technology, and greater delegation of project responsibility by corporate management.

Trends in the practices of the foreign competitors show an important part of the overall picture. Japanese trends show a strong emphasis on total product quality (e.g., launch of Acura, Lexus, Infiniti), perhaps at the expense of lead time and development productivity (total engineering hours per development project). However, in part because of the rise in the value of the yen, the pendulum between “cost is no object” quality and cost-effectiveness is rapidly swinging toward the latter. Nevertheless, the Japanese demonstrate a strong command of the link between product design and lean production. The European firms show lower rates of improvement at all levels, likely the result of a later and slower shift from traditional functional organization to project management. The Koreans have emerged as very competitive automakers in terms of lead time and development productivity, but lag significantly in quality.

Big 3 Assessment

The current sales success of the U.S. industry exploits some temporary conditions (e.g., exchange rates, popularity of traditional product types, cyclical market upturn). It is not due solely to elimination of previous corporate weaknesses.

The U.S. automobile industry has made significant operational improvements but still lags in mastery of the overall product development process. It is still not as adept at product development as certain competitors are, especially the Japanese (see corporate strategies and structures of the Big 3, discussed below). U.S. automakers should not rest on temporary success. The U.S. industry should avoid riding current good fortune and assuming that it will ensure continued success.

The current sales success of the U.S. industry exploits some temporary conditions. It is not due solely to elimination of previous corporate weaknesses.

Developing a robust product development infrastructure involves a number of initiatives: eliminating duplication in product development assets through reorganization, globalization, and alliances; developing platform and component set strategies across a portfolio of vehicle projects; defining critical areas of firm expertise and focus; creating strategic links to technology suppliers; and improving the way "lessons learned" are fed back into an interdisciplinary organization focused on new product development.

Customer demand for high levels of product quality, safety, reliability, and sophistication, even in the most economical vehicle classes, poses a major challenge, particularly in an information climate that rapidly disseminates reports on good and bad product attributes.

Implications of Vehicle Development Management Practices among the Big 3

There are enormous differences in how the Big 3 manage product development.

Chrysler Corporation

Chrysler's strategy emphasizes lean domestic product development featuring high integration with its suppliers and an increasing export focus. Chrysler has five platform teams that cover all U.S.-sourced products. All except Jeep and Truck are located in its new billion-dollar Chrysler Technical Center. Chrysler's U.S.-sourced product portfolio is limited to eight mass-production platforms. Its Diamond Star/Mitsubishi alliance is structured primarily to fill gaps in its model line. Chrysler produces exports to increase the utilization of U.S. plants and to build profits. The company has limited foreign production (minivans and Jeeps in Europe, Jeeps in China).

Chrysler has a high level of component outsourcing (about 70 percent). Its suppliers are increasingly engineering large built-up assemblies, such as complete instrument clusters. There is also growing reuse of components across platforms (e.g., engines across Neon JA model platforms). Its corporate structure incorporates a service function, platform teams, Tech Clubs, and a flattened organizational hierarchy.

Chrysler's corporate staff functions as a service organization for platform teams, manufacturing, and shareholders by allocating resources, setting strategic goals, and managing infrastructure.

Chrysler's corporate staff functions as a service organization for platform teams, manufacturing, and shareholders by allocating resources, setting strategic goals, and managing infrastructure. It avoids interfering with platform teams. The platform teams take clear responsibility for vehicle development, subject to corporate-allocated budget and vehicle design intent. Interdisciplinary activity is high in engineering, marketing, finance, styling, and manufacturing. Supplier participation is coordinated with the total design effort. There is consensus management of tradeoffs. The Chrysler Technical Center supports start-to-finish platform development with modern test facilities.

Chrysler's Tech Clubs—personnel working in the same system or component area (e.g., wiring, brakes, audio)—represent a "virtual" functional organization that maintains and disseminates technical knowledge across platform lines. Chrysler's flattened hierarchies have only five basic engineering grades (the original LH model project had one vice president, one general manager, five executive engineers, 25 managing engineers, and an engineering staff).

Ford Motor Company

Ford's global strategy, Ford 2000, has integrated global operations with global product alliances, segment management, and world-class timing. The Mondeo / Contour / Mystique "World Cars" are interlinked in Ford's Corporate Design network. Ford has a wide variety of alliances with Mazda (Escort and 323, Ranger and B2000, Explorer and Navajo), Nissan (Villager and Quest), Volkswagen (European Minivan), and Kia (Aspire), and there are corporate synergies with Jaguar and Aston-Martin. Ford's segment management divides each market by vehicle size and drive type and teams segment managers with vehicle program managers to identify and fill market niches from a joint business and technical perspective.

Ford is proficient at low-cost, high-quality manufacturing.

Ford is proficient at low-cost, high-quality manufacturing. However, Ford's own extensive benchmarking against Toyota and Chrysler has indicated both higher product development cost and deficiencies in its time to market. Its world-class timing initiative seeks to standardize the vehicle development process and shorten time to production (43 months or less from Program Definition to Job #1 for single body-style programs; 48 months or less for multiple body-style programs).

Ford's corporate structure comprises Automotive Operations, Vehicle Program Centers, and a balance of home organizations and dedicated teams. Ford Automotive Operations unites North American Automotive Operations and Ford of Europe, building on economies of scale from common systems such as the Ford Corporate Design network, its Worldwide Engineering Release System, and the Purchasing Release System. The rest of its operations are expected to follow in time. Ford's five Vehicle Program Centers in the United States and Europe divide development responsibility by vehicle size and drive type (four-wheel drive, rear-wheel drive) to supply global markets. Models are designed to carry high feature content to satisfy a variety of customer tastes.

Ford is attempting to arrive at a balance of power between core engineering groups and dedicated program teams. It encourages both advanced systems and technologies as well as highly marketable vehicles. Ford consciously avoids the Chrysler platform team model because management feels it fails to leverage Ford's central technical strengths and support a broad, interlinked vehicle portfolio.

General Motors Corporation

The strategy of GM is multifold, maintaining a coherent product portfolio, "Voice of the Customer" research, a standardized four-phase development process, strategic links between its North American and international operations, and organizational revitalization.

GM's North American Operations Car Platforms and Truck Platforms have replaced the former Chevrolet-Pontiac-Canada, Buick-Oldsmobile-Cadillac, and Truck and Bus groupings. GM's Platform rationalization is under way to support each brand's mission and achieve greater commonality of platforms and components. GM is aiming at unique variations on flexible engineering themes rather than a proliferation of unique systems (e.g., from 200 steering column designs in 1993 models to 50 in 1997–2000 models). GM has assigned a disciplined, mandatory application of a four-phase vehicle development process to all new products.

GM is making an increased effort to listen to the "Voice of the Customer" through Needs Segmentation market research—designing future vehicles to fit groups of people desiring similar attributes rather than predetermined size- and price-based market segments. GM's intensive consumer research has included over a million interviews since 1986.

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GM's structure is a matrix organization, with a Vehicle Launch Center and Centers of Expertise. GM's North American new product development (NPD) organization is run by four "heavyweight" executives, one each for engineering and design operations (Small Car Group, Midsize & Large Car Group); truck platforms (Matrix of Marketing Divisions—brands like Chevrolet and Pontiac); platform divisions; and vehicle groups (Small Car and Midsize & Large Car Groups).

The Vehicle Launch Center (VLC) monitors the first two years of vehicle development process (program proposal, concept development, and technology application) as the initial home for each new dedicated platform team. It co-locates the team with centralized marketing, engineering, manufacturing, planning, and design staff resources. The VLC acts as storehouse of NPD knowledge and has enforced documentation and business management practices.

GM's five North American Operations Technical Centers for design, engineering, manufacturing, research and development, and quality hold Centers of Expertise and support the Vehicle Launch Center with central staff experts and personnel loaned to platform teams.

At Chrysler, there is intense concentration of activities on a single project at a time with high group identification and few personality-driven product changes.

Development Organizations in the "Design Cultures" of the Big 3

Considered innovative, Chrysler Corporation's design culture is informal, direct, collaborative, and collegial. Design innovations are owned by the entire team and are taken up as challenges by engineering. At Chrysler, there is intense concentration of activities on a single project at a time with high group identification and few personality-driven product changes. The product design team maintains close working relationships between disciplines and with suppliers, has one-third union participants on the platform team, and maintains longer supplier relationships than the other companies in the Big 3.

Ford's design culture may be described as academic and introspective, but it is also pragmatic, with its business and technical groups in beneficial give-and-take with one another.

Ford's design culture may be described as academic and introspective, but it is also pragmatic, with its business and technical groups in beneficial give-and-take with one another. Individual Ford employees must develop networks across the company's large and complex organization to effectively carry out their tasks. Ford spends more time than Chrysler at process and organizational introspection, perhaps a result of having a greater number of technical and business specialists not directly engaged in platform activities. Ford also supports substantially more infrastructure than Chrysler, but less than GM.

The culture of GM has, to some extent, been characterized by extended chains of command, a complex matrix organization, and competition for resources. GM is attempting to address these issues and to improve communication throughout its organization. As a result, there have been substantial increases in communication and teamwork between GM's marketing and technical staffs.

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Impacts of Cultural Organization and Product Development Strategies of the Big 3

The product development strategies of the Big 3 are the result of decades of corporate practice increasingly influenced by foreign competition and other external factors. The response of each of these companies is reflected in its corporate culture and performance. Each of the Big 3 defines its issues differently than the other two, and the implications of these definitions are similarly divergent.

Chrysler Corporation

Of the Big 3, Chrysler has the highest per-vehicle profits and lowest break-even point, allowing it to expand its product portfolio and manufacturing capacity despite lingering concerns over quality. Chrysler has less infrastructure than the other Big 3. Its vehicle mix is more skewed toward high-profit minivans, and its sport utility vehicles contribute to its high net per-vehicle profit. The Neon platform, two manufacturing plants, and a new stamping facility were developed in 31 months for approximately $1.3 billion (an improvement over the LH platform—Chrysler Concorde, Eagle Vision, Dodge Intrepid—for which one plant and a retooled stamping facility were developed in 39 months at a cost of $1.6 billion).

Ford Motor Company

Ford and GM have much broader vehicle portfolios than Chrysler. Ford's vehicle mix is less heavily weighted toward high-profit minivans and SUVs. Ford has performed well, with strong sales but poor net per-vehicle profit and high warranty costs in 1994. Its CDW-27 (Mondeo) World Car program was costly, and its introduction of the new minivan (Windstar) was quickly leapfrogged by Chrysler's completely revamped minivan line. Ford's organizational structure and corporate culture—for example, its history of vehicle champions—have slowed its efforts to create cohesive and dedicated program teams. However, Ford's management is aware of the need to make lines of decision-making more direct and quicker, and organizational changes are in process.

General Motors Corporation

GM is attempting to be more responsive to the demands of the marketplace. Oldsmobile is furthest along in remaking itself in Saturn's image as a model of customer responsiveness. The Corsa model is a de facto World Car. The Saturn has been a cultural and sales success, although only a limited financial success.

In terms of performance, GM has had the lowest net per-vehicle profits of the Big 3, with continued problems in its minivan and family car markets and problems increasing content from its outside suppliers. Chevrolet, Pontiac, and Geo are below average in J.D. Power's Vehicle Dependability Study on five-year quality. But GM quality has been steadily improving: Cadillac, Buick, and Oldsmobile are in the top ten of the same study. Also, in some key segments (e.g., midsize car [Lumina] and small car [Citation]) it is very cost and value competitive compared with Ford's offerings (Taurus and Contour).

GM's relationship with the United Auto Workers is still strained: strikes over management attempts to outsource brake system calipers cost GM significant production losses in 1996.

TECHNOLOGY

The automobile is a highly engineered, sophisticated product that meets stringent reliability, durability, and social requirements. Its design, manufacture, and operation call more and more for cutting-edge technology. The Big 3 companies have a long history of aggressively pursuing research and development (R&D) to stay competitive, to meet the changing needs of the consumer, and to meet federal requirements. The diverse ways in which the companies meet these technology needs reflect their diverse corporate competitive strategies.

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General Motors Research has historically emphasized internal corporate research and is currently the top corporate investor in R&D in the United States, with a 1995 R&D budget of $8.4 billion—a 19 percent increase over 1994. It also employs more PhDs than any other private employer in the United States. While much of its work has been in central research laboratories, GM is placing much greater stress on the integration of its research efforts with the product planning of its car and truck divisions. The GM tech center in Warren, Michigan, reflects this change.[4] The center's R&D plans are more focused on the needs of its operating divisions and its customers; more speculative R&D has been reduced. The center is now organized as a business unit, with its research portfolio fully open to GM's product development community. The center's director has set a goal of placing 50 percent of projects into production in two to three years. Consideration is also being given to licensing GM inventions throughout the industry.

To meet its R&D needs, Ford relies on the Ford Research laboratory, which employs over 650 full-time scientists and engineers. In general, the objective of the research staff is to provide long-range technical leadership to the corporation worldwide. This means the lab is involved in a spectrum of activities ranging from the development of advanced product and manufacturing technologies to long-range, relevant research in key scientific and engineering disciplines. The research staff maintains a mix of long-, medium-, and short-range programs. Short-range efforts generally have a goal of solving immediate or pressing production problems and account for about 10 percent of Ford's efforts. Medium-range projects are directed toward specific goals to meet longer-term company needs and generally make up about 80 percent of Ford's efforts. Long-range programs are the least goal-directed efforts and make up the remaining 10 percent. Ford's research expenditures of $6.5 billion in 1995

[4] "GM Customers Get to Drive Latest Tech Center Research," *Detroit News* (Aug. 6, 1995).

made it the second largest U.S. corporate supporter of R&D, following GM.

Chrysler Corporation addresses the need for new technologies differently. Chrysler research and development efforts are split into two portions. Its Scientific Lab handles technical R&D and delivers technical expertise and services to the rest of Chrysler's platform groups. The second portion of its R&D effort is primarily handled by a small group known as "Liberty and Technical Affairs" and relates to advanced development efforts. This group addresses specific high-technology projects and develops ideas in the form of concept cars and government contract proposals. The two R&D groups work in concert to monitor emerging technologies, pursue new product concepts, and develop platform-focused products.

This historic public/ private partnership aims to strengthen U.S. global competitiveness, preserve American jobs, reduce our country's dependence on foreign oil, and improve the environment.

Cooperative Research and the Partnership for a New Generation of Vehicles

Complementing their individual efforts, the Big 3 automakers have also placed increasing emphasis on research collaborations with one another, with their suppliers, and with the federal government. For example in 1992, Chrysler, Ford, and GM created the United States Council for Automotive Research (USCAR) to facilitate, monitor, and promote precompetitive cooperative research. Through this cooperative effort, resources are coordinated more effectively to conduct research and evaluate alternative technologies to improve the automobile.

Besides working with each other to research and develop technologies for the next generation of vehicles, the Big 3 automakers are working with the federal government in a cooperative, precompetitive research effort called the Partnership for a New Generation of Vehicles (PNGV). Combining the technology resources of seven federal agencies, twenty government laboratories, and USCAR, this historic public/private partnership aims to strengthen U.S. global competitiveness, preserve American jobs, reduce our country's dependence on foreign oil, and improve the environment.

At an early stage of the partnership, the participants recognized the importance of involving the traditional base of automotive suppliers as well as some nontraditional sources of supply. Since that time, a special effort has been devoted to understanding the supplier community, recognizing its importance as a source of technical innovation, and finding means for its effective interaction with PNGV. Currently, more than 400 automotive suppliers and universities have joined in PNGV research.

PNGV has three mutually supportive, interactive goals:

1. Significantly improve national competitiveness in manufacturing.

2. Implement commercially viable innovations from ongoing research in conventional vehicles.

3. Develop environmentally friendly vehicles that can achieve up to three times the fuel efficiency of comparable 1994 family sedans (i.e., the 1994 Chrysler Concorde, Ford Taurus, and Chevrolet Lumina) without sacrificing performance, safety, or affordability.

Major technical improvements and innovations are needed to enable the U.S. auto industry to build this next generation of automobiles, which will operate with much higher energy efficiencies and safety levels and lower emissions than today's vehicles, while maintaining present performance, size, and utility standards. (See table 3, which lists some of the technical areas USCAR has identified as needing research and development.)

Table 3. USCAR's Focus Technical Areas

Technology Areas	Candidate Technologies
Advanced Lightweight Materials	Jointing technologies and adhesives Glass fiber, and resin fiber composites Metal matrix composites Ceramics Engineering plastics Aluminum, titanium, magnesium High-strength steel
Energy Conversion	Four-stroke direct-injection engines Gas turbines Fuel cells Advanced diesels
Energy Storage Devices	Ultra capacitors Advanced batteries (electrical vehicles or hybrids) Flywheels

Table 3. ***Continued***

Technology Areas	Candidate Technologies
Efficient Electrical Systems	Power electronics Advanced electric motors Efficient electric controllers (for regenerative braking, power management, signal distribution)
Exhaust Energy Recovery	Thermoelectric systems
Advanced Analysis and Design Methods	Structural mechanics Virtual prototyping Simulations Fluid dynamics
Reduction of Mechanical Losses	Tribology Lubricants
Aerodynamics / Rolling Resistance Improvements	Simulation tools New materials
Advanced Manufacturing	Supercomputing Agile manufacturing (programmable machines and tools, near net-shape casting) High speed data communication and data management Rapid prototyping (virtual manufacturing and complex visualization techniques) Advanced forging / joining techniques
Improved Efficiency of Internal Combustion Engines (Combustion Management)	Stratified charge / lean burn engines Direct injection Transient fuel control / fuel injection
Emissions Control	Advanced nitrous oxide exhaust catalysts Onboard diagnostics (evaporative systems, catalyst diagnostics, engine misfires) Advanced particulate traps
Fuel Preparation, Delivery, and Storage	Pressure vessels Hydrogen storage alternatives Reformers / fuel processors
Climate Control	Low emissivity windows Efficient heating, ventilation, and air conditioning

Table 3. ***Continued***

Technology Areas	Candidate Technologies
Advanced Crashworthiness/ Occupant Protection Technology	Structural design and advanced lightweight materials Computer simulation of vehicle crashes Advanced occupant restraint systems including sensors

Both the federal government and the automotive community are strongly supportive of PNGV, which is now in its third year. In working together toward national social and economic goals, this partnership is a unique departure from traditional approaches to achieving public policy objectives.

Increasing Use of Electronic Components

With both vehicles and transportation infrastructure incorporating more electronics into their systems, the auto industry will likely grow as a consumer of electronics components and as a driver of electronic technology development. Like many other industries, the automobile industry is rapidly increasing its use of electronic components. Virtually every aspect of driving a modern high-end automobile is controlled by electronics—acceleration, braking, seating, security, entertainment, navigation, driver information, crash protection, steering, etc. This trend is likely to continue. In addition, the automotive infrastructure—traffic control and guides, law enforcement, toll assessment, and the like—rely increasingly on electronic controls.

The auto industry will likely grow as a consumer of electronic components and systems and as a driver of electronic technology development.

As a result of both of these trends, the auto industry will likely grow as a consumer of electronic components and systems and as a driver of electronic technology development. Ford and GM, which are highly vertically integrated with electronics, are likely to benefit as the market value of their electronics divisions grows.

Adoption and Evolution of Lean Production Human Resource Practices

Labor-management relations, workplace innovations, and human resource practices play a pivotal role in the economic performance and competitiveness of the American auto industry.

Human Resource Management

Labor-management relations, workplace innovations, and human resource practices play a pivotal role in the economic performance and competitiveness of the American auto industry and serve as a bellwether and pacesetter for American industry in general. This has been the case from Henry Ford's moving manufacturing line and $5-a-day wage, to the "quality of working life" programs in the 1970s, to the present efforts to implement lean production models of work organization, human resource, and labor-management practices. These issues are tightly intertwined with technology and manufacturing strategies and practices. Indeed, the joint effects of these human and technical factors determine manufacturing performance.

Key Issues in Labor Relations

Demographics in the United Auto Workers

Automotive employment (particularly in the Big 3) has been hit by three important forces: (1) the industry has reduced its capacity; (2) the industry has improved its productivity, requiring fewer workers to make the vehicles demanded; and (3) global competition in the automotive supplier sector has resulted in a reduction in unionization. It has also resulted in a higher wage differential between employees of the Big 3 and employees of the supplier sector, who earn less. As a result, over the past two decades, the United Auto Workers (UAW) membership has declined and aged considerably. Few workers have been hired into UAW jobs in the past two decades and many low-seniority UAW members have lost their jobs. Moreover, a significant fraction of the UAW membership (estimated at 30 to 50 percent by some) will retire in the next decade. This is expected to lead to significant additional hiring and outsourcing by the Big 3.

Labor-Management Innovations in the U.S. Auto Industry

To preserve high-wage auto manufacturing jobs in the United States, many believe the auto industry must further the adoption of labor-management cooperation and workplace innovation, such as the Saturn and New United Motors Manufacturing Inc. (NUMMI) models and Chrysler's Modern Operating Agreements. Despite 20 years of significant Japanese competition in the auto industry, the penetration of cooperative labor relations is still low in the U.S. auto industry.

Why is diffusion of workplace innovations slower than expected in the U.S. auto industry? There is no consensus answer to this question. However, IMVP research, along with findings of a recent U.S. government commission,[5] suggests that the following factors are significant:

1. Limits on labor/management teams. American labor law restricts the forms of employee participation in non-union relationships and places limits on employee participation and workplace reforms in collective bargaining relationships.[6]

2. Union recognition. Support and diffusion are also limited by business and labor battles over the process of union recognition. The ability and willingness of employers to open and maintain non-union facilities and the frustrations experienced by workers and union when trying to unionize facilities in the face of strong managerial resistance continue to strain labor-management relations. These tensions make it difficult for union leaders to be unwavering champions of cooperation and innovation in relations with management. The cooperative relations and trust required to sustain workplace innovations within and across companies are not likely unless there is a de-escalation of labor-management conflict in new plants and new union organizations. The full benefits of these workplace innovations will not be realized until these larger conflicts are reduced.

3. Economic pressures. Economic pressures for downsizing, outsourcing, cost controls, and short-term performance compete

The cooperative relations and trust required to sustain workplace innovations within and across companies are not likely unless there is a de-escalation of labor-management conflict in new plants and new union organizations.

[5] Commission on the Future of Worker-Management Relations, *Fact Finding Report* (Washington, D.C.: U.S. Departments of Commerce and Labor, 1994).

[6] Thomas Kochan, Paul Osterman, and Martin M. Perline, "The Mutual Gains Enterprise: Forging a Winning Partnership among Labor, Management, and Government," *Relations Industrielles* 50, no. 4 (1995).

with long-term perspective. The diffusion of human resource innovations is constrained by the fact that these innovations have clear, immediate costs but uncertain long-term payoffs and by the relative unimportance of human resource policy in the strategic decision-making of American corporations.

Implications of the Key Issues in Manufacturing Plants and Human Resource Practices

Changing Labor-Management Relations, Workplace Innovations, and Human Resource Practices

Lean production is a composite of practices. For example, it links manufacturing policies with human resource / labor-management practices. The combination of these manufacturing and human resource practices produces the highest levels of manufacturing performance (quality, productivity, flexibility) in plants around the world.[7] Plants that invest heavily in automation and advanced technologies without changing their human resource practices perform poorly relative to those that take an integrated approach to technology and human resources.

The combination of these manufacturing and human resource practices produces the highest levels of manufacturing performance (quality, productivity, flexibility) in plants around the world.

By 1990, Japanese-owned plants in Japan and the United States had implemented more integrated human resource and manufacturing systems than U.S.-owned plants, which, in turn, had implemented more of these practices than European plants.

In 1990, as today, there was wide variance in U.S. practices. Many plants were still characterized by traditional labor-management and human resource management systems. The unionized transplants, such as NUMMI, had gone far in implementing lean production and labor-management systems jointly in a unionized environment. Some non-union Japanese plants had also implemented many of these features. Saturn, a new GM division, had implemented a unique co-management system jointly with the UAW.

From 1989 to 1994, U.S. plants continued to progress in adopting lean production practices and the associated labor-management and human resource practices. The latter practices have not moved as rapidly as in European plants, but the European plants had farther to go in achieving

[7] James P. Womack, Daniel T. Jones, and Daniel Roos, *The Machine That Changed the World* (New York: Harper Perennial, 1990).

lean practices. The performance gap between Japanese-owned plants in Japan and in the United States and U.S.-owned plants has narrowed but remains significant. Finally, the variance of performance within regions is often as great or greater than the variance between regions. Specifically, the survey data suggest the following:

1. Inventory has been reduced considerably in U.S. and European plants and in Japanese North American transplants. In the United States, inventory reductions have been achieved more through reductions in supplier stocks than from internal plant buffers.

2. U.S. plants have increased their use of teams, job rotation, and suggestion systems. However, the diffusion of these practices among Big 3 U.S. plants is proceeding at a much slower pace than in Europe. Japanese plants in Japan and in the United States continue to lead the world in the adoption of these human resource practices.

3. There is modest increase in the diffusion of human resource practices such as contingent compensation, investment in training, and reduction in status differences in the United States, rapid growth in Europe (and in Australia), and continued use of these practices in Japanese plants in Japan and the United States.

U.S. plants have increased their use of teams, job rotation, and suggestion systems.

These overall trends mask considerable variation across companies and individual facilities in the United States. Ford, for example, has followed a cautious, steady incremental change process that has built on its experiences in joint ventures with Mazda (in the United States and abroad). It has made less use of teams than GM or Chrysler but focused more heavily on use of various total quality management tools and methods (e.g., statistical process control).

Chrysler has a number of traditionally structured plants and a half dozen Modern Operating Agreement (MOA) plants in which the full range of lean production human resource practices are implemented for all workers through a joint union-management oversight and governance process. Chrysler also has several plants where many of these features are implemented without the full union-management governance process (Progressive Operating Agreement plants). Some case studies suggest that Chrysler MOA plants benefit significantly from this arrangement relative to its non-MOA plants.[8]

GM probably has the widest variation in experiences and practices. Considering the Saturn Corporation experiment and the NUMMI facility (owned jointly with Toyota), GM and the UAW have gone farthest among the Big 3 in experimenting with very different models of labor-management relations. Saturn, for example, has co-management structures and processes throughout the organization—from the shop floor to the strategic advisory committee that serves as Saturn's link to the GM parent, and across functional areas—from human resources to sales, marketing, and supplier relations. Yet GM also has many traditional plants and a large number of hybrid facilities that contain elements of both traditional and lean production manufacturing and work practices.

Even given this wide variation, the U.S. auto industry is farther along than many industries in the United States in introducing and diffusing workplace innovations. In Saturn, NUMMI, Chrysler's MOA plants, and certain other facilities, the auto industry also has some of the most visible models of transformed union-management relations that serve as benchmarks for other industries. At the same time, the auto industry continues to have many rather traditional or only partially modified union-management relations and collective bargaining activities, as well as a growing non-union foreign transplant segment.

Overall, the United States has experienced a significant expansion in employee participation and associated workplace innovations over the past 20 years.

This diversity mirrors the diversity of practices and the mixed levels of support for workplace innovations among management and leaders throughout American industry. Overall, the United States has experienced a significant expansion in employee participation and associated workplace innovations over the past 20 years. In the past decade, the labor movement has become more willing to support these innovations and has recently endorsed the principles of workplace innovation and labor-management partnerships. Yet, despite the growing support for workplace innovations, our best estimates indicate that only one-fifth to one-third of American workplaces are engaged in significant employee participation or related forms of workplace innovation.[9]

Other Issues in Human Resource Practices

In the mid-1980s, the UAW national leaders were advocates for new joint governance and more team-oriented approaches to plant relations. In the 1990s, however, they have been less committed to the approaches found

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[8] Malcolm Lovall, Susan Goldberg, Larry Hunter, Thomas A. Kochan, John Paul MacDuffie, Andrew Martin, and Robert McKersie, *Report on the Chrysler-UAW Modern Operating Agreement (MOA) Experiment* (Washington, D.C.: U.S. Department of Labor, 1991).

[9] Thomas Kochan and Paul Osterman, (1994).

at NUMMI, Saturn, and other plants. This fact is best illustrated by the series of plant-level strikes at several GM plants over issues such as contracting out, staffing levels, production standards, and related local issues. Thus, the future rate of diffusion of these workplace innovations remains uncertain.

Another important development in the U.S. auto industry in the 1980s and 1990s is the emergence of a significant and quite successful set of non-union transplant assembly plants. The only foreign-owned assembly plants that are unionized in the United States are joint ventures between GM, Chrysler, or Ford and a Japanese company. Toyota, Nissan, and Honda are operating their wholly-owned, non-union assembly plants in the United States. Toyota did so even after experiencing a high level of success in its NUMMI joint venture with GM and the UAW. Mercedes Benz and BMW are currently opening non-union assembly plants in the United States.

Moreover, a large number of new foreign- and domestic-owned auto parts suppliers have opened plants in the United States in the past 15 years and kept them operating on a non-union basis. Thus, while the Big 3 (Saturn at GM, several renovated or newly opened plants at Chrysler, and selected Ford plants) have moved to governance systems that expand the role of the union, a significant portion of the industry is moving away from unionism altogether. This trend adds more diversity to the industry and a good deal of frustration and bitterness on the part of the UAW.

Moreover, a large number of new foreign- and domestic-owned auto parts suppliers have opened plants in the United States in the past 15 years and kept them operating on a non-union basis.

Experimentation Case Studies

Twice in this century, the automotive industry has served as birthplace and proving grounds for fundamental innovations in the organization and execution of production. At the opening of the century, Henry Ford, the architect of the mass-production system, sifted through scores of ideas and performed thousands of experiments in the 20-year process of developing his system of production. Roughly a half century later, Taiichi Ohno, over a period of approximately 17 years (1948 to 1965), followed a similar path of constant experimentation, discovery, and innovation in developing the Toyota Production System. This tradition of constant experimentation in the search for improvements continues today in the auto industry—at the level of individual processes as well as at the level of the system of production.

Experimentation is the lifeblood of a healthy industry.

Such experimentation is the lifeblood of a healthy industry. Conversely, maintaining a stable system in a dynamic industry is almost a sure recipe for disaster. Few enterprises can expect shelter from Schumpeter's "winds of creative destruction" in today's world of increasingly open borders and tightly linked international economies. Organizations must experiment and grow to survive.

Given this mandate for learning, most automotive companies today are actively exploring possibilities for improvement. In this section, we mention a few of the more visible experiments of the past decade.

General Motors Seeks New Paths

No company in the world mastered Henry Ford's system of mass production the way Ford's crosstown rival did. GM leapt ahead of Ford in the 1930s and raced to become the world's largest industrial concern. However, by the 1970s, as it sat on top of the world, GM had become frozen in the paradigm it mastered. The path to renewal has been slow and arduous.

A number of GM plants have been very innovative in taking up the corporation's search for improvement in a world that has changed so dramatically since the early 1970s. Among these are the NUMMI plant in Fremont, California, a joint venture between GM and Toyota; the Saturn plant in Spring Hill, Tennessee; GM Europe's Opel plant in Eisenach, Germany; and the CAM-I plant in Canada.

NUMMI

GM's manufacturing plant in Fremont, California, closed its doors in 1982 because of poor quality, low productivity, and dismal labor relations. Two years later, the plant re-opened as the New United Motor Manufacturing Inc., under joint ownership of Toyota Motor Corporation and GM, using new management and labor policies but 80 percent of the UAW members who had worked there previously. IMVP researcher John Krafcik[10] studied the before-and-after of the Fremont plant and discovered that, with Japanese lean methods, the new NUMMI plant doubled the productivity of the old plant, cut worker absenteeism by 90 percent, and cut the rework area in half with the installation of the "pull cord" system (in which workers on the assembly line pull the cord when a defect is detected, halting the system and allowing mass-produced errors to be eliminated). A low-tech operation, the NUMMI plant proved that a

[10] John F. Krafcik, *Learning from NUMMI* (Cambridge, Mass.: IMVP and Massachusetts Institute of Technology, 1986).

plant did not have to be on Japanese soil with Japanese workers in order to be lean and successful. The plant demolished many myths about the nontransferability of lean production to the United States and to American workers.

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Saturn

Also in the mid-1980s, GM's decision to create a "different kind of a car company" from the ground up resulted in the Saturn Corporation. The Saturn plant in Spring Hill, Tennessee, provides a case study of a close labor-management partnership on the factory floor. Saturn has also created a unique partnership among the company, its dealers, and the car-buying public. Saturn leapt to the upper echelons of the closely watched J.D. Power customer satisfaction surveys (recently rated third behind Lexus and Infiniti) and sets the standard for other dealerships on many dimensions.

On the labor relations side, Saturn is a highly visible experiment with a new model of labor-management relations and organizational governance—one that challenges and departs from many of the customs, legal doctrines, and adversarial patterns of traditional U.S. industrial relations. Both the workers and the management at Saturn agreed from the start that they would distance themselves from the bureaucracies of GM and the UAW. It was an alliance between workers and management that has been pathbreaking in U.S. labor relations. The GM employee contract is seven inches thick, but Saturn's labor contract or "Memo of Understanding" is a scant 28 pages, covering everything including how the plant is managed. The agreement eliminated a number of sacred cows, such as the right to strike during the term of contract.

Saturn has also created a unique partnership among the company, its dealers, and the car-buying public.

Eisenach

GM Europe's Opel plant at Eisenach is an example of a European enterprise embracing the principles of lean production.[11] In 1989 the Eisenach plant, located in the then-moribund German Democratic Republic, was a morass of inefficiency producing an obsolete vehicle called the Trabant. GM purchased the Eisenach plant and brought in the best of lean expertise through the Kaizen Institute of Europe, a Japanese-based institute that teaches the values and methodology of lean enterprise. A new manufacturing plant was built in 1991–92, and intensive worker training introduced lean manufacturing methods. Problems were solved along the way, and lean principles were learned, built up, and implemented. The new plant is

[11] See discussion of Eisenach GM plant in Paul Ingrassia and Joseph B. White, *Comeback: The Fall and Rise of the American Automobile Industry* (New York, 1994).

already competitive with Japanese companies, is a vanguard plant for Opel and the rest of the European auto industry, and is on an upward curve of efficiency and quality.

Toyota Tinkers with Success

Toyota Motor Kyushu

As the present decade opened, one of the biggest concerns among the major Japanese auto companies was that they would run out of labor to staff their factories in Japan.

As the present decade opened, one of the biggest concerns among the major Japanese auto companies was that they would run out of labor to staff their factories in Japan, which seemed to face limitless demand for their automobiles. In 1993, two million Japanese 18-year-old males—the primary raw material for Japan's auto factories—entered the workforce. In 2010, only 1.2 million 18-year-old males will enter the workforce—a 40 percent drop. In 1990, just before Japan's "bubble economy" burst, the auto industry got a taste of what a labor shortage might be like. With much new found affluence and the growth of the financial and other service sectors, young Japanese began voting with their feet—against working in auto plants. The industry discovered that, despite the famed worker involvement through the *kaizen* process, car making, even in the highly touted lean production system, was, at its core, strenuous and unpleasant work. Some concluded that the greatest threat to the Japanese auto industry was the coming labor crunch.

One solution to such a labor crunch would be to import more labor or cars into Japan to make up for any impending shortfall. (For example, Toyota has planned to import a small number of U.S.-made Chevrolet Cavaliers and Pontiac Sunbirds.) Another strategic option would be to reduce the labor content in automobiles through greater automation. A third would be to make automobile manufacturing jobs more attractive to Japanese citizens, competing more effectively on the labor market and shifting the labor shortfall to some other sector. The latter strategy is closely associated with the "humanization" movement, whose roots are primarily European. The movement was epitomized by the Uddevalla plant and its craft production environment with hours-long work cycles for many laborers rather than the repetitive 60-second cycle common in Japanese plants.

Toyota attempted to address the anticipated labor shortfall using both greater automation and by making the jobs more labor-friendly. Toyota launched a new manufacturing company inside Japan—Toyota Motor Kyushu—and endowed it with new, automated, state-of-the-art, worker-friendly technology.[12] Built at a cost of $1.5 billion and in continuous operation since 1992, the plant does stamping, body assembly, painting, and final assembly, in addition to making bumpers, instrument panels, and suspension systems. Subsequently, due to an increase in the value of the yen and a stubbornly stagnant Japanese economy, the domestic labor shortage has turned to a surplus, perhaps reducing the strategic value of this plant.

Toyota Motor Motomachi

The Toyota Motomachi plant uses a different style of human resource practices in the assembly of the new four-wheel drive RAV4.[13] Innovations include noise control, ergonomic interior design, and minimal use of robotics. The assembly line has a conventional overhead conveyor but is subdivided into five parts with buffer zones in between, relieving considerable stress on the workers. Automation has been cut back by two-thirds and is used only on rolling devices that move engines and gearboxes into position for human assembly. Toyota's rationale for reducing automation came from its own studies, which revealed that automation had reduced the number of line workers but had increased maintenance personnel.

Toyota's rationale for reducing automation came from its own studies, which revealed that automation had reduced the number of line workers but had spawned a whole new generation of maintenance personnel.

Producing 428 cars a day, the Motomachi plant may well have set a new benchmark for productivity, with a reported ten man-hours per vehicle. Though the success of the plant is attributable to Toyota management skills, some key ideas have been adopted from U.S. competitors, particularly Chrysler and Ford, which have also been reducing the number of parts in new models through value engineering techniques. Toyota plans to have each new model built with 70 percent of the parts common to earlier models. This plan has already saved Toyota nearly a half billion dollars. Supplier involvement in the design and engineering of full subassemblies has contributed considerable savings to Toyota, and more savings are expected in coming years.

These examples, selected from two of the largest automobile companies, are but the tip of an enormous iceberg of experimentation in the industry. Every auto company in the world—large and small—is striving to find competitive advantage through innovations in products, technology, and systems management.

[12] C.H. Fine, "The World's Quietest Factory," draft, Massachusetts Institute of Technology, Sloan School of Management, Cambridge, Mass., 1995.

[13] See [Toyota City], "The Kindergarten That Will Change the World," *The Economist*, March 4, 1995, 63–64.

Automotive Components Supply Chains

Supply Chain Policies

The world's automotive manufacturing sector consists primarily of about 20 very large multinational corporations. The automotive supply sector, however, comprises thousands of firms ranging in size from a few employees to more than 100,000. Drawing conclusions about such a large and diverse sector is much more difficult than for the manufacturing sector.

Best practice in automotive supply chain management involves close, trusting relationships with long-standing suppliers that are intimately involved with the development and production of the components and subsystems they provide. The work of Kim Clark and Takahiro Fujimoto[14] sheds much light on how outsourcing product development activities through "black box parts" reduces overall project lead time and engineering resources required for product development. In the past five years, Chrysler has aggressively incorporated those findings into its modus operandi, GM has largely rejected that philosophy, and Ford has settled somewhere in between.

Best practice in automotive supply chain management involves close, trusting relationships with long-standing suppliers that are intimately involved with development as well as production of the components and subsystems they provide.

On the surface, the advice to improve partnerships along the supply chain, drawn largely from Japanese practices, seems to have significantly helped Chrysler on its return to growth and profitability. At the same time, GM insists on exerting extreme price pressure on its suppliers and aggressively negotiating division of the returns to innovations in supplied parts and subsystems. Some believe that this posture was responsible for the company's slow recovery from the recession of the early 1990s. However, GM estimates savings of $4 billion per year from this approach. GM is relying on its strong technical capabilities and its ability to bargain suppliers down on price to achieve its cost reductions. Chrysler, on the other hand, is encouraging its supplier-partners to find more ways to cut costs through cooperation and incentives to split gains.

[14] Kim Clark and Takahiro Fujimoto, *Product Development Performance* (Boston: Harvard Business School Press, 1991). Kim Clark, "Project Scope and Project Performance: The Effect of Parts Strategy and Supplier Involvement on Product Development," *Management Science* 35, no. 10 (1989): 1247–63. Takahiro Fujimoto, "The Origin and Evolution of the 'Black Box Parts' Practice in the Japanese Industry," Working Paper No. 94-F-1, University of Tokyo, Faculty of Economics, January 1994.

In Japan, the rise of the yen has driven significant amounts of automotive assembly off the islands, delivering a quadruple shock to the Japanese supply base. First, domestic demand for Japanese-made parts is declining due to the decline in domestically assembled vehicles. Second, Japanese manufacturing plants are looking offshore to import cheaper parts (and in some cases severing those long-term partnerships). Third, demand from non-Japanese manufacturing plants is declining due to the increasing cost disadvantage of Japanese domestically produced parts. Fourth, competitors of Japanese suppliers (in North America, for example) are growing stronger as they hone their lean production skills by supplying the growing demand for North American-made parts from the Japanese transplant production. Conversely, North American automotive suppliers are enjoying a quadruple bonanza thanks to the same four phenomena: (1) rising North American production volumes, (2) growing opportunities to export to Japan, (3) reduced competition from Japanese-based (yen-dominated) suppliers, and (4) increased rate of learning from Japanese transplant customers. For the near future, U.S. automotive suppliers should continue to reap gains as long as they continue to improve and the yen does not lose significant value against the dollar.

Key Issues in Supply Chain Relationships

Arm's Length vs. Partnership in Supplier Relations

We discuss here two kinds of supplier-assembler relations. The first is a short-term, arm's-length relationship with minimal flow of information between supplier and assembler. This type of contractual relationship has traditionally characterized most supplier-assembler relations in the mass-production system, particularly in the United States. One of the features of 1980s lean production is a relatively long-term relationship between assembler and supplier, characterized by a rich flow of information between the two. These partnership relationships, the second type of supplier relation, tend to continue indefinitely or carry the implicit promise of renewal at the end of a specified contract. The partnership relationship is exemplified in the Japanese-style multifirm organizations called *keiretsu*.

One of the features of 1980s lean production is a relatively long-term relationship between assembler and supplier, characterized by a rich flow of information between the two.

When supplier responsibility for product development and investment is not an issue, the arm's-length relationship is often sufficient and partnership relations would be superfluous. Furthermore, while Japanese-style partnerships have economic benefits, they are costly to set up and maintain and may reduce a customer's ability to switch away from inefficient suppliers. But when the supplier's responsibility includes involvement in the development of new or altered parts, Japanese-style partnerships become increasingly advantageous to both parties and tend to result in superior performance all around. Partnering firms (1) share more information and are better at coordinating interdependent tasks; (2) invest in relation-specific site, human, and physical assets that lower inventories, improve quality, and speed product development; and (3) rely on trust to govern the relationship, which is a highly efficient governance mechanism that minimizes transaction costs for both parties.[15]

The Challenge of Moving from Arm's Length to Partnership

Assembler-supplier partnerships are important vehicles for speeding product development, sharing risks and resources, and accessing technology and knowledge.[16] Though U.S. firms have moved toward adopting keiretsu-style partnerships, the process has often been slow due to entrenched attitudes and long-standing suspicion between suppliers and assemblers from decades of competitive bidding and short, arm's-length contracts.

But there are deeper economic and social factors that increase the resistance to supplier-assembler partnering in the U.S. auto industry. The Japanese community-oriented culture inherently fosters more goodwill among firms than the American culture of "rugged individualism" and social heterogeneity. These cultural differences may explain why partnering between companies is taking time to become established in the United States.

Many U.S. firms have now acknowledged that the Japanese system has a number of advantages over arm's-length relationships in automotive supply chains. Whether U.S. industry will widely embrace these practices or develop hybrids of Japanese and U.S. strategies to achieve tighter and more productive supplier-assembler relationships remains to be seen. However, the case of Chrysler, discussed later in this section, offers strong evidence that American firms can successfully and profitably implement the partnership model.

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[15] Susan Helper, "Supplier Relations and Investment in Automation: Results of Survey Research in the U.S. Auto Industry," Sept. 1991; Sako, 1992; Dyer, forthcoming.

[16] Toshihiro Nishiguchi and Jeffrey H. Dyer, "Strategic Industrial Sourcing: The Japanese Advantage," *Administrative Science Quarterly* 40, no. 1 (1995).

Slow Adoption of Innovative Human Resource Practices among U.S. Suppliers

As with the adoption of partnership relations with customers, the record with respect to adoption of partnership with employees is mixed. On the positive side, 92 percent of supplier plants had quality circles, and on average, 56 percent of those firms' employees had attended a meeting in the six months before the survey was mailed in summer 1993. On the other hand, 38 percent of the plant managers who responded to the survey said they did not know (even within 10 percent) how many suggestions workers had made in the past year. Those who did know said half of the suggestions had been implemented on average.[17]

Slow Adoption of Innovative Practices with Second-Tier Suppliers

Supplier relations with second-tier suppliers are sluggish and well behind the lean advances being made in supplier-assembler relations. Only about one-third of U.S. suppliers offer multiyear contracts or technical assistance to a majority of their own suppliers. Moreover, only 40 percent have a majority of suppliers who participate in product design or produce just-in-time.

Supply Chain Management

Future Directions for Big 3 Supply Chains

Only 29 percent of U.S. suppliers had relationships with their most important customer that could be classified as partnership relationships.[18] GM has actively moved away from partnership relationships with its suppliers. The average length of contracts GM offers has fallen about 40 percent, from 1.8 years in 1989 to just over one year in 1993. GM also has set up a system of worldwide competitive bidding, saving an estimated $4 billion per year in the prices it paid for parts between 1992 and 1994.

Despite the advantages to GM, some suppliers say they will refuse to supply new technology to GM due to its policy requiring quotes from prospective suppliers and complete technical information on the product and its manufacture, free of any claims of confidentiality.[19] Such

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[17] Susan R. Helper and Laura Leete, "Human Resources Policies and Performance in the Auto Supply Industry," working paper, Case Western Reserve University, Cleveland, Ohio, 1995.

[18] Susan R. Helper and Mari Sako, "Supplier Relations in Japan and the United States—Are They Converging?" *Sloan Management Review*, Spring 1995.

a one-way partnership relationship is unpalatable to some suppliers. GM officials acknowledge that this policy means that GM will have to continue doing most of its product development in-house in order to ensure apples-to-apples comparisons among supplier bids. This strategy could result in GM's losing the advantages of supplier participation in product development.

On the other hand, the U.S. auto industry has made some significant strides toward partnership relationships since 1989, even taking into account the GM experience. For example, 80 percent of U.S. suppliers now provide their customers with detailed information on the steps they use in their production process—up from 50 percent in 1989. These new U.S. figures are equal to the percentages in Japan's supplier-assembler partnership relationships. The information suppliers provide is crucial to the adoption of techniques such as value analysis / value engineering, in which the production process is streamlined to eliminate waste. Similarly, the participation of U.S. suppliers in product design now matches the Japanese. U.S. suppliers now far outpace the Japanese in the percentage of the sales that come from products not produced five years ago: United States, 20 percent; Japan, 5 percent.[20]

On the other hand, the U.S. auto industry has made some significant strides toward partnership relationships since 1989. For example, 80 percent of U.S. suppliers now provide their customers with detailed information on the steps they use in their production process—up from 50 percent in 1989.

Chrysler continues to devolve responsibility onto its suppliers. For example, TRW is working to integrate the passenger-side air bag into the instrument panel designed with another supplier, even though it means that TRW will no longer deal directly with the automaker on this product. However, most parts are still not provided in particularly large systems, meaning that the manufacturing plant must accommodate a great deal of complexity. The median supplier to the Big 3 assembles only four parts to make the component it supplies to the automaker; in contrast, the median Japanese-owned supplier to a Japanese assembler located in the United States assembles 12 parts.[21]

Several of the Japanese-owned assemblers (Honda and Toyota in particular) have established intensive technical assistance programs for their U.S.-based suppliers. For example, in Honda's BP program, a team including Honda technicians, supplier managers, and supplier workers studies one process for several months and makes suggestions to im-

[19] *Automotive Industries,* July 1994.

[20] Helper and Sako, "Supplier Relations."

[21] Susan Helper, "Supplier Relations and Performance in the U.S., Japanese and European Automotive Industries" (paper presented at the IMVP Research Briefing Meeting, Berlin, 1994).

Chrysler Corporation has significantly restructured its outsourcing through a streamlined and geographically more accessible system of third-party logistics services.

prove it. This process has led to 30 to 40 percent improvements in quality and productivity in that area for each of the few dozen suppliers that have tried it.[22]

Case Study: Chrysler's Supplier Logistics

Chrysler Corporation has significantly restructured its outsourcing through a streamlined and geographically more accessible system of third-party logistics services.[23] In all, Chrysler has considerably reduced the number of logistic providers. For example, the number of truckload suppliers has been reduced from 250 to 30, coordinated by only one lead truckload provider. The number of less-than-truckload suppliers has been reduced from 25 to just one. Chrysler has 2,600 suppliers shipping a total of 34,000 parts from 3,300 locations. The corporation has 38 facilities, three logistics centers, and 15 manufacturing plants. At both its Belvidere and Sterling Heights manufacturing plants, Chrysler has reduced the number of locations of supplier shipment points by around 40 percent and has significantly reduced the average distance from supplier point to manufacturing.

Chrysler's plant in Bramalea, Ontario, offers an insight into creative utilization of existing facilities. Because it is manufacturing beyond its original capacity, the Bramalea plant is outsourcing more than most auto plants, integrating direct supplier sourcing (40 percent of volume) with flow-through warehousing (45 percent of volume) and a sequence center (15 percent of volume). The sequence center, which is 25 minutes away, supplies 14 different commodities (600 of the total of 4,600 parts) in order of assembly. The order ("broadcast") is sent out 45 minutes before the first commodity is to be assembled and three hours before the last. All inbound logistics activities have been outsourced to one lead logistic provider, Customized Transportation Inc., which operates a dedicated system for Chrysler. Its activities include transport, the warehouse and center described above, and outbound flow of returnable containers, dunnage, and other garbage. The plants at Sterling Heights and Belvidere have also been assigned one lead logistic provider.

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[22] John Paul MacDuffie and Susan Helper, "Creating Lean Suppliers: The Honda Way," working paper, Case Western Reserve University, Cleveland, Ohio, 1996.

[23] "Professor Sten Wandel Speaks on Third Party Logistics Services," *IMVP News*, Fall-Winter (1994–95): 11ff.

Distribution, Retailing, and Postmanufacturing Industries[24]

Automotive distribution and retailing were once given little attention because they were viewed as adjunct to the core business of engineering and manufacturing vehicles. However, in the past several decades, the pressures on the industry to make its factories and product development processes more efficient have spilled over into the distribution and retailing (postmanufacturing) sectors—cutting profit margins and causing significant restructuring in the distribution and retail industry base.

This restructuring, although quite significant, has attracted much less attention than the manufacturing sector's changes because it involves no dramatic dislocation of people, jobs, or economic base. These downstream segments of the supply chain are experiencing a shift from being capital intensive (focused on inventory investment) and people intensive (sales forces) to being more information intensive (having the right vehicle in the right place at the right time). Due to greater flexibility of labor and capital in the postmanufacturing markets, this conversion from physical logistics to information logistics is shifting the power and leverage in the supply chain toward economic agents that are highly entrepreneurial and flexible.

Due to greater flexibility of labor and capital in the postmanufacturing markets, this conversion from physical logistics to information logistics is shifting the power and leverage in the supply chain toward economic agents that are highly entrepreneurial and flexible.

These economic forces have reduced the number of dealers in the United States (now approximately 22,000) and are expected to continue doing so. More important than the absolute dealer count is the trend toward segmentation of the many industries that make up distribution. Preliminary research reveals early development of a number of new business structures and methods. Following are brief discussions of key trends emerging in this diverse industrial segment.

Key Issues in Distribution, Retailing, and Postmanufacturing

Unlike the small group of relatively tightly organized supply chains, the postmanufacturing sector is a much looser collection of organizations that are not so centrally focused around the automaker. Since most of these organizations are driven directly by customer behavior rather than assembly scheduling, their activities are constantly shifting and

[24] This section is based on the research of Martin Anderson, Associate Director, IMVP.

appear to be far more random than activities organized in the production portion of the value chain. Industrial performance in the post-manufacturing sector is determined by a set of loose linkages, constantly negotiated among a wide variety of independent companies, including automakers, parts suppliers, dealers, transportation companies, information services companies, advertising and marketing organizations, consumer groups, fleet owners, vehicle auctions, financial providers, and independent service and repair organizations. Since much of the control of this portion of the value chain occurs within the jurisdiction of state laws, local policy issues are often far more important at this end.

If an automaker wants to improve its premanufacturing efficiency, it can focus suppliers on relatively homogenous performance measures throughout the linked production chain, such as manufacturing hours per vehicle or quality targets. If an automaker wants to improve its postmanufacturing inventory management, however, it faces a much more complex array of players and relatively few homogenous measures of performance.

IMVP site interviews show that interdealer transfers (cars shipped between dealers to match local demand patterns) can range from as low as 5 percent to as high as 50 percent of sales within a single brand, depending on the dealer and the region. This finding indicates that both dealer and region can represent significant factors for profitable and efficient distribution.

A central issue is now emerging in automotive distribution—how to create incentives and commercial relationships among a number of players with different agendas in order to meet new competitive mandates for improved distribution performance.

Dealers within a single brand may create dramatically different positions with their customers. Some may adopt a Saturn-like “no haggle” posture; others may openly publicize the fact that they negotiate prices. There are high performers and low performers in all of these categories. Early research shows that diversity proliferates in this system that many have considered to be uniform.

Thus, improving the distribution system will be quite different from improving the factories in the supply chain. Inventory control—a strategic pillar of distribution—requires orchestrating the behavior of car salespeople, dealer-owners, market data companies, transport companies, national and local advertising and promotion channels (television, radio, print, on-line), capital suppliers, and others. None of these players are owned by the automaker, and many are not contracted directly to the auto company.

A central issue is now emerging in automotive distribution—how to create incentives and commercial relationships among a number of players with different agendas in order to meet new competitive mandates for improved distribution performance.

The principal U.S. auto industry challenges of the past 15 years were (1) to reduce the quantity of work required to make a car, (2) to reduce the defects in each car, (3) to reduce the resources required to develop a new car and bring it to market, and (4) to reduce the overhead of running the supply and manufacturing system. The massive response to these challenges has stemmed the growth rate in production costs by reducing waste in each factory and by better coordinating relations between factories in the supply chain. Now, at a time of growing global competition, the next challenge is to reduce wasted effort and cost in distribution. Given the relative diffusion of organizations in the postmanufacturing sector, this new challenge raises a number of related issues:

- How to better capture and process customer requirements
- How to better link rapidly changing customer requirements to a comparatively less flexible production system
- How to better match specific vehicles to customer requirements
- How to speed delivery after the purchase agreement is concluded
- How factories and automotive manufacturing companies can best cope with rapidly diversifying types of retail and distribution channels
- How manufacturers might best relate to the growing number of multibrand retailers
- What major strategic changes will occur in the core franchise system, given the potential created by new information technologies
- The implications of global changes in postmanufacturing practices

Automotive marketing, distribution, and retailing represent approximately 20 to 30 percent of the value of a new car.

The Major Role of Distribution and Retailing in the Automotive Value Chain

Automotive marketing, distribution, and retailing represent approximately 20 to 30 percent of the value of a new car, depending on company, dealer type, and the level of sales incentives applied to the product line. Automotive markets generate more than $1.5 trillion in revenue worldwide every year, of which approximately $500 billion is generated in the North American region. Almost one-third of this value is directly created by retailing of new and used vehicles, service and repair, and related postmanufacturing activity.

Perhaps more important, many of the keys for a successful manufacturing company are held by players in the postmanufacturing sectors. Retailers, customer researchers, forecasters, distributors, financial sources, and others define what the manufacturing sector should make and how and when it should make it, because they have direct contact with the wishes of the ultimate customer. Manufacturing organizations that do not heed the information embedded in the complex postmanufacturing networks suffer poor sales, high inventories, and tarnished reputations with customers. In the past, with less competitive markets, auto companies could afford the often hidden costs of high retail inventories. Now, all manufacturers must find new ways to limit these costs by understanding customer needs and by listening carefully through the various layers of retailing and distribution.

Making Distribution Lean

Factories are beginning to address the problems of sluggish auto distribution pipelines. Having learned the lessons of just-in-time inventory in manufacturing, virtually every car company is trying to extend such streamlining into the distribution and retail portion of the value chain. With tens of billions of dollars tied up in slow-moving inventory, the potential payoff has become clear. The challenge is to coordinate the diverse collection of organizations to collectively recapture some of that cost.

The most common innovation is to change the structure of field inventory to more closely align the slower, less flexible factory manufacturing schedule with the rapid changes in customer demand, while simultaneously reducing total field inventory. Rover and other European companies have been innovative with various forms of stock pooling and order processing. Most American-based factories are launching similar efforts. Perhaps most widely publicized are the Cadillac experiments that pool all the Cadillac inventory in a region (e.g., Florida) for availability to any dealer in the region.

The central thrust of these efforts is to allow individual vehicles to remain unclaimed until the “sales moment,” to allow them to “float” flexibly through the stocking system. Doing so can dramatically increase the likelihood that an individual vehicle will reach an exact match buyer. In the traditional system, production units are usually locked into a specific delivery path before or shortly after manufacturing, and they queue up in field inventory or sell at a discount (or both) because they are not precisely matched to a specific buyer.

Most observers expect major innovations in physical inventory distribution and the supporting information infrastructure during the next five years. Some companies clearly envision a form of "produce to order" in the car business within 10 years.

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The Role of Information Technology in Selling Cars

As in all of retailing, the information technology revolution portends dramatic change in the automotive industry. Electronic data systems provide the mechanism for much of the new and used car supply industry. Increasing information systems and controls have kept dealers in business as margins have become very thin. Major advances in technology will allow better matching of factory production and changing consumer tastes, resulting in leaner distribution patterns.

The postmanufacturing businesses are beginning to show a huge appetite for new electronic services, and it is reasonable to expect that this growth will fuel corresponding growth in the computer and electronics sector. Given the potential of new information technology systems demonstrated by both the factories and advanced dealers, the auto retailing sector seems destined to become a significant electronic systems market during the next ten years.

Information technology for the postmanufacturing business falls into the following categories:

- Technologies that enhance the existing business structure
- "Spec-ing" systems that allow salespeople to match factory options to customer needs more accurately and to create a more accurate demand forecast
- In-house training and service management systems that connect factory engineering expertise to all technicians in a within-brand dealership
- Customer outreach systems linked to factory-sponsored advertising and marketing
- Technologies that will accelerate current trends toward nontraditional distribution structures

- Customer relation systems (via the Internet or similar customer-oriented media) that allow brokers or order takers to become viable economic organizations (reducing significantly the role of traditional dealerships in many transactions)
- Analogs to shop-by-phone or catalog channels
- Retail systems that allow mega-dealers to solidify their multibrand positions (similar to the systems that support mega-retailers like Wal-Mart)

Auto retailing can adopt many dimensions of the mail-order or direct-sell computer business.

An automobile is such a major purchase for most people that it will always require some form of physical retailing by dealers. However, auto retailing can adopt many dimensions of the mail-order or direct-sell computer business. A consumer information industry has already arisen in the auto sector over the past three decades. Now any customer can find the information needed to negotiate the purchase of a new or used car without visiting a dealer or using any factory-sponsored information. This freedom allows customers to shop independently before going to a dealer.

There are many more window-shoppers for cars than there are buyers, although these window-shoppers do represent future buyers. Increasing numbers of customers are window-shopping through information sources, many of which are being rapidly converted to the electronic media. Through on-line services, the Internet, toll-free numbers, and cable television, shoppers now have enhanced opportunities early in their decision cycle to find information and be guided to the choice of an appropriate vehicle, comfortably in advance of the time they actually make their purchase.

In short, there are now many more ways to retail cars than setting up a street corner dealership, running television commercials, and hoping someone comes in to buy a car currently on the lot. Now buyers can be identified well in advance, and their shopping experience can be tailored to their personal buying style and timing. The implications are considerable for the rest of the automotive industry in terms of forecasting, production scheduling, inventory and financial control, and even product planning.

Independence and Diversification of North American Dealerships

Much postmanufacturing activity, especially in North America, is not controlled by the automakers. Industry players in distribution and retailing often act quite independently from the factory as they market automobiles. Moreover, distributors and retailers often work with more than one car manufacturer at the same time. Although dealerships carry factory brands, the dealer may not be as dependent on the factory as an automotive component supplier is; a distribution organization can potentially source its products globally—from any auto producer in the world.

A unique, often confusing, characteristic of the retail sector in North America is the delicate balance of power between factory and dealer created by a network of state laws and the franchise contract. The dealer needs a franchise contract from the manufacturer to sell that manufacturer's cars. The manufacturer's control is not insignificant: Along with the franchise requirement, the factory can control the location and style of prospective dealerships. However, in most states the dealers enjoy protections from the factory. Moreover, the rise of mega-dealers is resulting in an increasing retail power over the factory.

Estimates of the used car market vary significantly, but it is clearly much larger than the new vehicle market in terms of number of units sold per year. Because new car margins for dealers have become significantly lower than used car margins, used car sales often subsidize the new car sector. Service and repair are labor-intensive industries that create significant local employment. Used car auctions have become multibillion dollar industries and are responsible for building a national infrastructure of used car supply that rivals the supply power of new carmakers in many ways.

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Many dealers have emerged as major stand-alone businesses and are beginning to redefine the postmanufacturing markets. An increasing number of dealers have annual revenues in excess of $1 billion. Many more have annual revenues in the hundreds of millions of dollars. These powerful corporations are responding to customers and are creating multibrand shops that cross over many factories. They can also negotiate for large blocks of high-quality used cars, which further insulates them from any one automaker.

The best known example of this new type of mega-dealership is the growing and successful used car chain CarMax. Owned by Circuit City, the $6 billion publicly traded consumer electronic company, CarMax is a chain of no-haggle dealerships with inventories of about 1,000 top-of-the-line used cars at each location. Circuit City uses inventory control and computer technology to control costs and to guide and inform customers about the products offered.

The foundation of Saturn's success is that its entire value chain, from raw material through used cars, is coordinated to provide a pleasurable buying and driving experience for its customers.

There are five CarMax stores operating on the East Coast, with projections for 50 U.S. dealerships by the year 2000. Eventually CarMax and similar operations may be players in the new car business as well: Chrysler has already agreed to sell CarMax a new car dealership in the Atlanta area.

Other dealers specialize in certain forms of retailing by selecting customer niches. For example, companies are emerging that specialize in leasing specific classes of autos such as sports cars. These retailers are counting less on volume and more on developing strong customer relations for repeat business.

The most notable specialty segmentation is that represented by the Saturn Corporation. The foundation of Saturn's success is that its entire value chain, from raw material through used cars, is coordinated to provide a pleasurable buying and driving experience for its customers. While other companies and many retailers have instituted high customer satisfaction policies, no other company has yet completed such an extensive systemwide overhaul as Saturn.

Other dealers are experimenting with selling by phone or catalog-style retailing. Some dealers associate with buying clubs (e.g., those formed by unions, employers, the American Automobile Association, or other groups) and thereby get access to "pre-sold" customers who do not want to spend much time shopping. One dealer takes telephone orders; another sets up shop on the Internet. The amount of electronic retailing has soared since mid-1994, and new technologies have made possible a whole new structure for the auto retailing industry.

One Example of Retail Innovation: The Saturn Corporation

The Saturn Corporation has developed partnering relationships with its dealers, a lean concept previously untested by the Big 3. In less than three years, Saturn established itself as one of the strongest brands in the compact car segment while foreshadowing the revolution in automotive retailing in the United States. Saturn's distribution and retailing system has achieved high market share and customer satisfaction since its inception in 1985.[25]

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[25] J. Chris Koenders and Wujin Chu, "A Case Study of Saturn's Distribution Strategy" (paper presented at the IMVP Research Briefing Meeting, June 1993).

Saturn's innovative marketing strategy began with the objective of taking market share away from Japanese imports in the United States. Saturn's market planning team examined retailing best practices in a number of companies, both automotive and nonautomotive. They saw a customer-pull instead of dealer-push marketing strategy as the solution.

To achieve customer satisfaction, Saturn fostered relatively few dealerships—fewer than 200 in 1993 (only 10 to 20 percent of the number of dealerships for other major manufacturers' divisions in the United States)—thereby encouraging high unit sales per store, with Saturn allowing the retailer to add satellite outlets as demand increased. Moreover, Saturn's partnerships with its retailers empower those companies to be involved in the decision-making councils of the Saturn Corporation.

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Saturn retailers have avoided the pitfalls of undesirable salespeople by hiring completely new personnel in a rigorous screening process. Low turnover in sales personnel has been indicative of the success of this method. By following a consistent pricing policy, Saturn dealers eliminate the stressful negotiating process in which customers can feel "had" by dealers. Customers are shown a sheet with a grid illustrating the retailer's price schedule according to model and options. Consistent pricing appears to withstand cyclical fluctuation between strong and weak demand periods. Saturn's distribution strategy allows the company to respond better to market fluctuations, mainly because it is in closer touch with the market. Fewer layers of management, along with information technology and the integration of retailers into the decision-making bodies of the corporation, ensure that feedback is immediate and appropriate action can be taken quickly.

Saturn's distribution system has clearly been highly successful, but it must be adopted in full by the retailer in order to work; the components of this system are interrelated and have been constructed to function as a single coherent strategy. Its considerable competitive success is directly attributable to the unanimous embracing of these principles by Saturn and its retailers.

Urban Multibrand Retailers

Another form of retail innovation, multibrand retailers may be as important as the Saturn innovation, although less publicized to date. This type of innovation is sparked by individual car dealers that have become successful enough to gain independent financial resources.
In some ways, multibrand dealers are the opposite of the Saturn ap-

proach. Saturn seeks to form a deeper partnership between a fairly narrow single brand and a dedicated body of single-brand dealers. The other form of innovation assumes that it is best to strengthen a multibrand position while obtaining a firm position with a large retail buying population. This is the most effective distribution and retailing model in almost all nonautomotive industries and might be considered the Wal-Mart or Circuit City approach.

In this case, the innovative dealer organization will become highly responsive to the customer since a key to the business is a large and loyal customer population. This approach leads to many innovations such as roving demo cars driven to customers' work or homes, easy-order toll-free numbers, a wide variety of financial purchase or lease options, and a host of other customer-driven systems that vary by region and market style.

On the supply side, this kind of organization will try to get the best vehicles from a large number of factories, just as Circuit City tries to get the best-selling televisions from a number of television manufacturers. This strategy involves setting up systems that help the factory (i.e., the dealer itself becomes a desirable customer) and matching the factory supply to customer demand by creating sophisticated forecasting and inventory management systems.

Conclusions

The postmanufacturing sector of the auto industry has always been important but has received little attention from auto manufacturing executives. However, distribution has become so critical to overall strategy that the sector is receiving much more attention than ever before. The sector is extremely diverse and is not necessarily amenable to the same tight coordination that auto manufacturers are building into their premanufacturing supply chains. However, linking the distribution sector to the manufacturing sector is the key to attaining better responsiveness to customers and to achieving competitive advantage.

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Innovators like CarMax are introducing a totally different dimension—strong independent companies that are not tied to any particular manufacturer and that have the muscle to negotiate attractive conditions with several manufacturers. The manufacturers will have to adapt to this new reality if they are to profit from the economies possible in the distribution system.

Regulation of Automobiles to Meet Social Objectives

Mobility, Economic Development, and the Automobile

Mobility and Transportation Congestion

Increased mobility and economic development have progressed in unison, and advances in transportation and associated infrastructure have been leading indicators of a nation's prosperity. The automobile, as a source of increased individual mobility, has been a particularly significant factor in bringing about economic growth and social change.

The automobile has reconfigured urban landscapes and influenced lifestyles in the United States and in other parts of the developed world. The United States and the other developed countries rely primarily on the automobile to provide personal mobility. Figure 14 shows the significant increase in auto travel in the United States, Europe, and Japan since the 1970s.[26] Although the United States is considered the most auto-oriented society, Europe and Japan are now adopting the same orientation, and auto ownership is increasing at a faster rate in these areas than in the United States.

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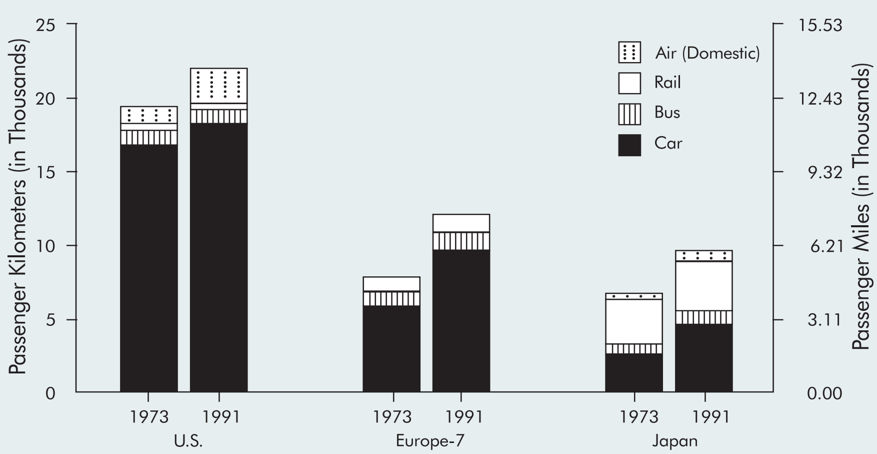
Figure 14. Per Capita Travel



Note: Air travel data for Europe-7 not available.
Source: LBL-IES Transport Studies.

[26] Lee Schipper and Maria Josefina Figueroa, "People on the Move: A Comparison of Travel Patterns in OECD Countries," Draft, International Energy Studies, Energy Analysis Program, Lawrence Berkeley Laboratory, University of California, Berkeley, Calif. (1994).

A massive increase in automobile usage is also occurring in developing countries, where mobility is absolutely essential to the development process. As figure 15 shows, developed countries typically have 300 to 600 cars per 1,000 population, but many large developing countries have fewer than 10 cars per 1,000 population. While the market for automobiles in the developed countries will continue, the major growth will occur in the developing countries.

However, a number of factors, including traffic congestion resulting from aging, overloaded roads, are reducing society's ability to maintain, let alone improve, mobility. Society's ability to address and resolve these concerns is critically important to the future of the automotive industry.

Congestion has advanced from an urban concern to a regional concern that affects entire metropolitan areas. From 1982 to the present, the percentage of urban areas in the United States with major congestion problems increased from 22 percent to nearly 50 percent, and it is still increasing. According to an Organization for Economic Cooperation and Development survey of 114 U.S. cities, congestion is severe to very severe in 33 percent and a worsening problem in 68 percent of the surveyed locations.

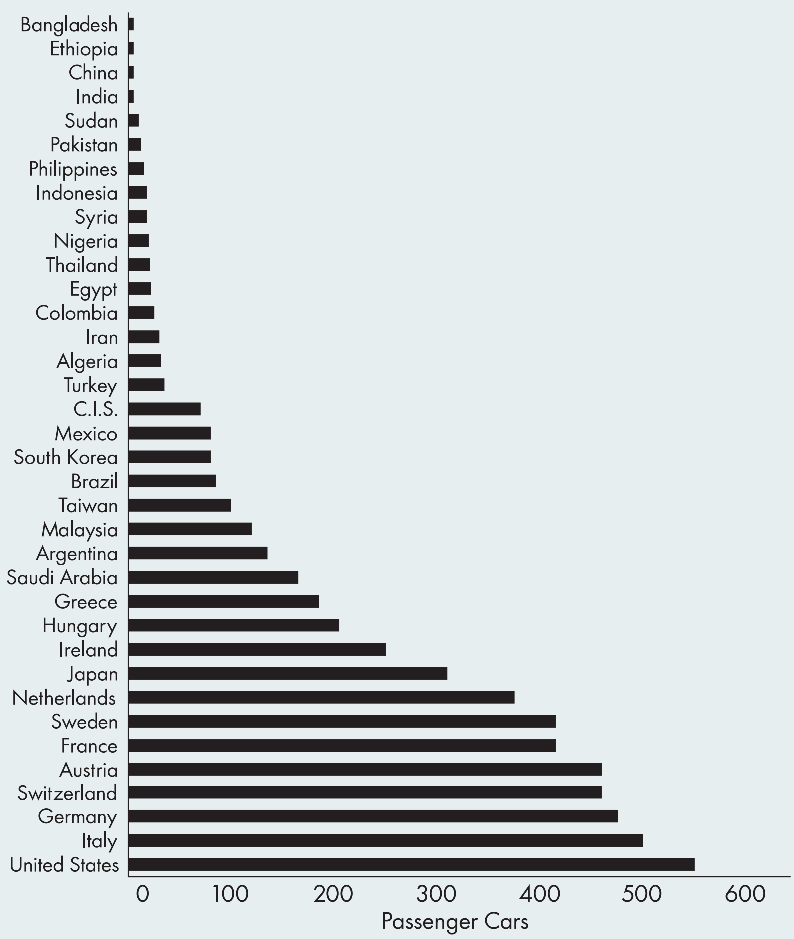
Nor does it appear that public transportation systems can provide either an alternative to reliance on the auto or a means of resolving congestion. These systems provide mobility primarily to individuals without access to an automobile (typically the young, old, poor, and handicapped). Even the best systems in the United States cannot satisfy more than a relatively small fraction of mobility needs. In spite of large capital and operating subsidies, public transport's worldwide share of travel has not increased and is not likely to increase in the future. David Bayliss, chief planner for London Transport, has just completed a global assessment of public transportation systems. He concludes that, even if the current rate of growth of metros continues, this "would barely keep up with the growth of urbanization and would mean that the metros' share of the rapidly expanding urban travel market would slowly fall."[27]

The Information and Communications Revolution and Future Mobility Needs

Information and communication technologies will greatly affect both the need to travel and the means of travel and may address transportation

[27] David Bayliss, "UITP Public Transport Panorama," Draft, London Transport Planning, June 1, 1995.

Figure 15. Passenger Cars per 1,000 Population



Source: AAMA

*Information and communication technologies will greatly affect both the need to travel and the means of travel and may address transpor-
tation congestion.*

congestion. These new technologies will enable the development of intelligent transport systems (ITS) in which the guideway (road), the driver, and the vehicle are integrated to enhance individual mobility and help to control congestion.

Drivers will be able to request information on the best routes based on travel conditions. A visual display will give the driver navigation instructions. In addition, since the information system is aware of the status and location of all cars, various transportation system management strategies can be used to optimize the flow of vehicles. These strategies may include traffic light synchronization, ramp metering (and other forms of flow control), and electronic toll collection.

ITS provides a framework to operate a dynamic, coordinated system of mobility services, responding to both consumer demands and social concerns. Most projects focus on the middle range of the capacity spectrum—improving areawide traffic flow, with potential improvements in capacity estimated to be 10 to 30 percent. At the high end of the spectrum are vehicle control strategies that significantly increase the vehicle capacity of roadways. These strategies include “car following,” which will reduce the space between cars, and “lane control,” which will allow more lanes to be used in a right of way. Vehicle control strategies can also improve safety through object detection and collision avoidance systems. At the low end of the spectrum are the control of roadway capacity through pricing or traffic rationing policies. The real-time control system allows these policies to be implemented on an as-needed basis.

ITS may provide a foundation for a new vision of mobility for the 21st century. However, implementation of an ITS strategy will be most effective if it can be coordinated nationally and internationally. With numerous technology choices and significant new market opportunities, extensive entrepreneurial activity and experimentation will motivate the innovation process. At the same time, the public sector has a significant stake in these systems, both as the owner of the roadways and as the potential operator of resulting traffic management systems. Furthermore, the need for system compatibility extends across national borders, making some international coordination necessary.

ITS represents an interesting market opportunity for automotive companies. BMW, Daimler-Benz, and Volkswagen have teamed with Bosch and several other firms to implement ITS in German cities. General Motors has been an active participant in several ITS projects in the United States. As these examples suggest, ITS may provide automobile manufacturers an opportunity to expand their business to include providing broader mobility services.

Safety Concerns and the Automobile

The level of safety achieved by today’s vehicles far exceeds what was available several decades ago. While government regulation has played an important role, changes in consumer preferences and in public attitudes have also been important factors. The cumulative impact of government regulations requiring seat belts, padding, reinforcements, and a myriad of other features has made vehicles much safer in the event of a crash. In addition, our transportation infrastructure, particularly the interstate system, incorporates more safety features.

Auto safety has also improved as a result of consumer demand for safety features that go beyond current regulations, such as air bags and antilock braking. In other words, safety sells—even though safety regulations have added about $1,000 to the average selling price of passenger cars since 1980. Finally, society's attitudes toward intoxicated drivers, a major cause of traffic accidents, have hardened quite dramatically over the past few decades; a drunk driver is more likely to be viewed today as a callous criminal than a wayward reveler.

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Environmental Concerns and the Automobile

In many ways, the automobile epitomizes the environmental challenge of today. It is a large consumer of a critical and limited fossil energy resource; in many countries it is the largest contributor to man-made greenhouse gas emissions and brings large amounts of lead into contact with people; it is the prime cause of urban smog; it is noisy and contributes to congested cities; and its manufacture produces an array of emissions, including those from the mining and production of steel and the painting of auto bodies. In spite of great strides in the technical performance of individual vehicles, many problems remain.

The environmental challenges the automobile industry faces today are radically different from those it has confronted over the past three decades. These differences arise from major changes in their technological, economic, and political context, and their resolution will require a serious reexamination of the corporate and governmental institutions with which the automobile industry must interact.

Automobile Technology and Environmental Initiatives

Automobile technology has followed a trajectory of ever-increasing utility and complexity, both in general and with regard to the environment. Today's automobiles are vastly cleaner, more efficient, and less harmful to the environment than their 1970s counterparts.[28] A whole series of environmental issues (such as the automobile recycling crisis of the 1960s; the need to reduce airborne emissions of lead, hydrocarbons, carbon monoxide, and nitrogen oxides; the need to increase fuel economy; and more recently the global banning of chlorofluorocarbons) have

Today's automobiles are vastly cleaner, more efficient, and less harmful to the environment than their 1970s counterparts.

[28] See Motor Vehicle Manufacturers Association Auto Industry Statistics.

been largely resolved through technologies that enable automakers to provide an economical product with equivalent (if not better) performance while meeting environmental objectives. Today the industry faces environmental challenges that raise complex and controversial issues and which can best be resolved with the full involvement of both government and industry. Today, the industry faces environment challenges that raise complex and controversial issues and that can best be resolved with full involvement of both government and industry.

Zero-emission vehicle

Although there is no such thing as a zero-emission vehicle (pollution will be created *somewhere* by the construction, use, and disposal of the vehicle), a number of initiatives bear this rubric. Spurred by the California clean air standards, the zero-emission car initiatives exemplify technology-forcing regulation. In spite of researchers' best efforts, electric battery technology critically limits even the most advanced electric car to roughly 100 miles between charges. With advanced battery technologies still years away from production, automakers must rely on lead-acid batteries, with the concomitant introduction of more lead, rather than less, into the automobile materials cycle. Furthermore, the influence of such vehicles on net air quality is increasingly in question, particularly in light of the continuing, documented air quality improvements arising from the replacement of old vehicles with newer ones.

Weight reduction

Reducing the weight of the automobile has been a design strategy since the onset of the Corporate Average Fuel Economy standards, both by reducing vehicle size and by reducing weight through material substitution. However, material substitution is not a simple process. Changes in materials require changes in manufacturing technology, which is constrained by the economics of large-volume production. Henry Ford's assembly line would have been infeasible had he chosen to employ the traditional automobile material of his era, wood. It was his choice of steel, which could be formed and joined in seconds, that made his assembly line feasible and cost-effective.

Today, considerable efforts are aimed at finding ways to process lightweight materials within the current automaker production line target of 75 vehicles per hour. Many advanced materials are available and are used in applications ranging from sporting goods to advanced aerospace vehicles. However, none of them are fabricated in ways even remotely compatible with the rates of automobile manufacture.

Vehicle recycling

Recycling in the United States is entirely a private industry undertaking, composed of a large and profitable infrastructure of dismantlers, shredders, and nonferrous metal processors supplying used parts and secondary metals. Recycling has emerged as an environmental issue for the automobile over the past five years, primarily in response to European initiatives, but it is actually a relatively old issue—one that has already been resolved once. For cars that are recycled (90 percent of the total manufactured), roughly 75 percent of the vehicle's mass is recovered and reused. But this means that 32.5 percent of all material that goes into automobiles in the United States is not recovered (most of it becomes landfill).

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Today's automobile recycling research is focused on the unrecycled content of the vehicle, particularly its polymeric content. An adjunct issue is the remaining 10 percent of cars that are not recycled at all. Automobile plastics are currently employed to improve vehicle safety (in interiors) and to reduce vehicle weight to save fuel and reduce emissions. These crucial materials largely become landfill because of the complexity of the plastic blends and the difficulty of recovering them through recycling. However, some analysis suggests that the benefits of reductions in weight and fuel consumption of composites, even if not recycled, may outweigh the costs of lower recycling rates.

These environmental initiatives illustrate the key technological problem facing the automobile industry today. In each case, there are critical tensions among the technologies available to meet the initiative, the cost of their implementation, and their impact both on traditional measures of vehicle performance and on these newer indicators of performance. For example, if cars are to be largely composed of polymer composites, how are they going to be recycled? If the zero-emission vehicle is going to use batteries, how are the toxic heavy metals usually associated with batteries kept out of the environment? And how is vehicle safety maintained, when the vehicle's mass is reduced by 50 percent? Is the reduction of landfill consumption through increased recycling worth the net increase in energy used to run recyclable vehicles?

Diverse Approaches to the Regulation of Auto Manufacture and Use

As the preceding discussion indicates, increased mobility, via the automobile, has caused serious social concerns—allocation of scarce land resources for transportation infrastructure, depletion of finite energy resources, and detrimental environmental and safety impacts. Governments have responded to these concerns in many different ways. They have limited new roadway construction, invested in public transport systems, attempted through transportation system management practices to squeeze more out of the existing infrastructure, implemented vehicle inspection and maintenance programs, and, in some cases, introduced auto use disincentives, such as increased fuel taxes, auto-free zones, and road pricing. A few metropolitan areas have considered more draconian measures such as limited bans on driving if severe pollution conditions develop.

The approach to regulation of the automobile varies significantly by country, reflecting different social priorities. Vehicle recycling is a high priority in Germany but of far less concern in the United States. Noise pollution from automobiles is a higher priority in Europe than in the United States. On the other hand, urban air pollution is a higher priority in the United States, particularly in areas such as Los Angeles, than in other countries.

The United States has relied on the Corporate Average Fuel Economy regulations aimed at automobile manufacturers to improve fuel economy rather than on an increased gasoline tax focused primarily on drivers.

One example of the diversity of approaches is the use of gasoline taxes as a means of controlling auto use. The price of gasoline is $3 to $5 per gallon everywhere in the world except the United States, where the price is $1 to $1.50 per gallon. The United States has relied on the Corporate Average Fuel Economy regulations aimed at automobile manufacturers to improve fuel economy rather than on an increased gasoline tax focused primarily on drivers.

U.S. auto regulations tend to focus on new cars to achieve social objectives. An example is urban air pollution. It is estimated that less than 10 percent of the vehicles are producing 75 percent of the pollution. Removal of these “clunkers” is far more cost-effective than additional regulations on new cars. There are several ways to remove old vehicles. France and Spain have used vehicle buyback programs giving credits for trading in clunkers, and private industry has implemented “cash for clunkers.” Devices to detect the highest polluting vehicles could also be used on the roadway instead of, or to supplement, vehicle inspection programs.

The differences in national approaches to regulation lead to a serious design problem for the manufacturers, which are under increasing competitive pressure to make their products for international markets. Conflicting national and regional regulations discourage such global approaches and may inhibit the competitiveness of the manufacturers. Indeed, national regulatory requirements might be used not to achieve social objectives but as a trade barrier to favor local manufacturers.

Harmonization of international regulatory approaches and standards will help auto manufacturers adapt to globalization of markets. Furthermore, the regulatory process would be improved by requiring the consideration of interrelated social objectives, since regulatory actions to achieve one social objective, such as reducing air pollution, might have adverse effects on other social objectives.

Finally, there are alternatives to the command-and-control regulatory approach embedded in many U.S. regulations. The creation of public-private research collaborations in the PNGV project reflects a novel approach to the technological challenge of controlling the environmental impact of the automobile. Market-driven strategies such as road pricing and emissions trading are also gaining more support. Company-based initiatives to improve the product and production process are also attractive alternatives to government-imposed regulations.

Supply chains are long and complex, and there are many important players both upstream and downstream of the major manufacturers.

Summary and Conclusions

This study synthesizes our understanding of a complex global industry. It seeks to identify important trends,[29] competitiveness issues, and topics relevant to public policy. The most important points are these:

1. The automotive business is played out on a worldwide stage. Supply chains are long and complex, and there are many important players both upstream and downstream of the major manufacturers. Furthermore, long supply chains exist within the major manufacturers as well. Consequently, competition can be thought of as occurring between supply chains (e.g., Nissan's vs. Ford's), with the added complexity that these chains may share common elements (e.g., component suppliers, dealerships, or even jointly developed products). Competition may also occur within supply chains (e.g., a manufacturer and component supplier each may want to add significant and unique value to the vehicle's electronics capabilities). Speed and flexibility (agility) in detecting shifts in market opportunities and reconfiguring the supply chains to respond to the opportunities will be the important rent-earning assets.

2. Although private sector companies dominate many aspects of the industry in the developed world, governments have historically played, and will likely continue to play, major roles in shaping the industry. The U.S. government has significantly influenced the emissions, economy, and safety features of cars. The government of China will likely decide which companies will be allowed to participate in the development of China's automotive industry as well as the rules of that development.

3. Although the auto industry is often referred to as "mature," dramatic changes in product and market leadership, technology, distribution channels, and even the geography of production have occurred in the past two decades.

4. Sales volume is likely to continue its exponential growth in developing countries, and comparatively flat demand will continue in the developed world. As a result, much of the new

[29] Industrial history is littered with predictions that look foolish in hindsight. Therefore, some of the projections based on current trends are bound to be wrong.

investment and perhaps many product innovations will occur in the developing world. Therefore, production volumes, real wages, and working conditions are likely to improve significantly in the developing world. Developing countries such as Korea hope to become significant exporters, above and beyond satisfying their burgeoning domestic markets.

5. Severe competition is likely in every segment of the supply chain, driving innovation in business models and causing continued turbulence in the standings of different players. Global sourcing is not likely to disappear; however, it will be tested as to when it is optimal for the entire manufacturing-to-delivery process. In some cases, tight links with longtime partners may give better overall performance than use of lowest cost global suppliers.

6. Especially in the developed world, public sector pressures to make vehicles safer and more environment-friendly are unlikely to abate. These pressures will drive research and innovation in powertrains, fuels, electric vehicles, and lightweight materials. Given the twin pressures of government regulation and product competition, car companies that can develop and implement innovations in their supply chains are likely to benefit significantly in finding low-cost ways to meet requirements and put customer-desired features on the vehicles.

7. Cost competition will continue to encourage World Car concepts that amortize development efforts over more production units. Government regulations that are not harmonized across borders will continue to limit (at least to some degree) the attainable gains from this strategy, giving companies ample reason to lobby for improved regulatory coordination.

8. Predicting industry concentration trends is very difficult. For every argument for consolidation, there is another to support the contention that new competitors will surface. The economics of development and manufacturing support concentration, but the splintering of the distribution chain, the geographic dispersion of market demand, and the possible radical shifts in technology (e.g., nonferrous electric vehicles) may encourage disaggregation.

Especially in the developed world, public sector pressures to make vehicles even safer and more environment friendly are unlikely to abate. These pressures will drive research and innovation in powertrains, fuels, electric vehicles, and lightweight materials.

9. The industry will continue as a knowledge-intensive industry, as opposed to just cutting, forming, and joining metal. Consequently, intellectual asset development—in manufacturing, marketing, engineering, etc.—will increase as a key competence for all firms. Strategies that jettison intellectual capital in response to cost pressures are likely to lead to ruin in the longer term. Firms should continue to experience significant returns on improved human relations throughout the organization and into the supply chain.

10. As in many other industries, electronics will continue its inexorable march into the product. Designers have myriad ideas for increased electronic control of the vehicle, and consumers seem to like such features. The continued shrinkage in cost and size of electronic components also makes them attractive. More broadly, the use of electronics will increase for control of the entire transit system, as well as on board the vehicle. These trends are likely to shift more economic power to the suppliers and integrators of automotive electronics technology.

11. Finally, we expect that the automotive industry will continue to be thought of around the world as "the industry of industries," due not only to its sheer size in the economy of nations, but also to the high-dimensional complexity it exhibits. On so many dimensions—product complexity in design and manufacture, number of product attributes important to customers, process technology variety, supply chain size and complexity, rate of globalization, intensity of government involvement, complexity of labor relations, and impact on the landscape of human lives—the automobile industry presents a scope of management challenges whose complexity dwarfs that of most other industries.

APPENDIX A: THE U.S. SUPPLIER BASE AND MEXICO: A CASE EXAMPLE OF GLOBALIZATION[30]

For decades, the auto industry in the United States was concentrated near the Great Lakes. In 1975, half of all U.S. auto production (both parts and assembly) occurred in just 16 of over 3,000 U.S. counties. By 1990, however, these 16 counties accounted for only one-third of a similar level of automotive employment.[31] A significant amount of automotive employment has moved out of the United States entirely: As of 1994, the top 15 U.S.-owned suppliers to North American manufacturing plants employed 130,000 people in Mexico.[32] Much more employment has moved a shorter distance—to the Japanese transplant cluster just south of the Great Lakes region.

However, this trend has positive aspects. For example, suppliers located outside the old geographical "agglomeration" tend to have more partnership-like relations with their manufacturer customers: The suppliers are significantly more likely to trust their customers and treat them fairly and also more likely to provide their customers with information about their process steps.

Suppliers located outside the old geographical "agglomeration" tend to have more partnership-like relations with their manufacturer customers.

Negative aspects of this geographical shift include farther travel for parts, which reduces the ability to implement JIT and causes more traffic congestion. It has also meant a drop in employment in the areas where the supply industry was once dominant. While overall employment in the auto supply sector (SICs 3714 and 3465) remained relatively constant between 1975 and 1990, Wayne County, Michigan, lost 18,000 jobs in this sector over the same 15 years—more than one-third of its total 1975 employment level.[33]

Despite the growth in employment in Mexico, the Mexican supply sector has a long way to go to be world-class. Mexican-owned suppliers, which are typically small shops (maquilas) without sophisticated quality assurance or product development techniques, find it difficult to attain cost and technology advantages over competing foreign suppli-

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[30] See Kaye Husbands, "The Competitive Advantage of the Mexican Auto Parts Industry: Past Strategies, Current Capabilities, Future Outcomes," Draft Proposal, Williams College, Williamstown, Mass., 1995.

[31] Helper, 1993.

[32] *Automotive News*, March 13, 1995.

[33] County business patterns data cited in Helper, 1993; Herzenberg, 1992.

ers. Only a few large Mexican automotive suppliers that are associated with an industrial group or that are engaged in a successful strategic alliance with a foreign firm are likely to be competitive in price, quality, delivery, and service. Some of the reasons for this problem follow.

- **Smaller scale of production in Mexico.** Mexican parts plant managers and corporate executives report that their input costs are often significantly higher than those of their foreign competitors and that it is difficult to create low-cost products because of lower production volumes in their plants compared with foreign plants.

- **Inefficient use of labor.** Though manufacturing techniques of Mexican suppliers take advantage of relatively lower labor costs by using relatively more labor-intensive processes than their U.S. competitors, the employee turnover rate is much higher in Mexico (six times that in the United States). Training costs and missed learning curve economies therefore elevate the cost of operation.

- **Incomplete integration of statistical process control (SPC).** SPC is not prevalent among Mexican suppliers, and many of the firms that use SPC have not used it to adjust their production processes. For example, many companies claiming to have JIT in fact have significant stores of material or have shipping bottlenecks.

- **Absence of CAD/CAM.** Most Mexican suppliers get involved in the middle of the product development process or even later, partly because of the lack of CAD/CAM systems, other product development tools, integrated information commerce, or the human capital necessary to contribute to the product development and engineering processes.

Human Resource Management Issues[34]

Though Mexico is often considered a prime location of low-cost auto production in North America due to low Mexican wages, recent evidence based on a simulation study suggests otherwise.[35] Because of the low wages (about $2 per hour before peso devaluation, including fringe benefits in maquiladoras), low education (typically sixth grade), and high turnover (90 to 100 percent), it is difficult to implement lean production policies such as quality circles and worker suggestion systems that produce continuous improvement.[36]

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Supplier Issues

The use of Mexican suppliers depends not only on their capabilities but also on their strategic fit in the auto manufacturer's global supplier network. The head of supplier management at a U.S. manufacturer in Mexico indicated that 97 percent of its Mexican suppliers are certified at the basic level, but none of those suppliers is likely to receive full-service supplier status; once the company has one or two traditional suppliers that can design a given product it is not necessary to certify yet another supplier at that level. Only Mexican suppliers that have already earned world-class status and that can compete with foreign suppliers on price, quality, and deliverability will be part of the global supplier network at the first tier. Of these suppliers, few, if any, will gain status as full-service systems integrators. The other suppliers that remain in business will most likely become second- or third-tier suppliers to OEMs or producers for the aftermarket.

[34] Husbands, "Competitive Advantage."

[35] Ibid.

[36] Helper, 1995.

APPENDIX B: REGULATORY POLICY AND HARMONIZATION

The type and meaning of regulations affecting the automobile industry vary widely from one region or country to another. For regulatory control to produce maximal benefits, there should be interregional agreement on the standards and metrics of regulation (or at the very least a method of translating the metrics of one regulatory system to another).

For regulatory control to produce maximal benefits, there should be interregional agreement on the standards and metrics of regulation (or at the very least a method of translating the metrics of one regulatory system to another).

Firms with assets devoted to multinational business such as the world auto industry will benefit from regulatory harmonization that maximizes the use of their assets.[37] They will oppose divergent regulations that inhibit effective use of assets. On the other hand, firms with investments specific to a given domestic market may fight regulatory convergence, which threatens their investment by making entry easier for outsiders and will support heterogeneous regulations. Firms with investments featuring low "asset specificity" (i.e., those assets that are mobile or have valuable alternative uses) may relocate to less restrictive regulatory environments. Such movements facilitate heterogeneous regulations in what might be termed a "competition in laxity" among regulating regions.

Dominant, established firms in concentrated markets are well positioned to shape regulatory environments to their advantage. With higher market shares, they can capture a larger proportion of regulatory benefits. Because of their size and wealth, they may have greater resources to achieve their regulatory goals through lobbying, funding, research, public relations, and differential absorption of regulatory costs.

Dominant producers in highly concentrated industries or markets are likely to fight for regulations that provide (1) direct monetary subsidies, (2) constraints or subsidies on substitutes or complements of commodities produced, (3) price fixing, and (4) control over entry by new rivals. Environmental justifications for regulation may foster profits by legitimating principles for regulation and by adding environmentalists to regulatory coalitions.

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[37] Oye and Maxwell, 1994.

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