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Automobiles:
Strategy-Based Lean Production System

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Abstract

The present situations and future prospects of the Japanese automobile industry are discussed. Selected topics in this paper include the following: analyses of the basic product-industry characteristics of the automobile (e.g., product architecture); the mature of the dynamic competition in the world auto industry; competitive performance (e.g., productivity) of the Japanese auto makers; organizational capabilities of better Japanese firms in production, development and procurement; overall environments in the 1990s; the concept of "balanced lean" system and its adaptation to environmental changes; new flexible production systems that cope with volume fluctuation; architectural strategies of the auto firms; modularization of parts; M&A and alliance; future of the automobile technologies and architectures; future of the capability-building competition.

INTRODUCTION

About a hundred years have passed since automobiles came into being at the end of the 19th century. Indeed, the 20th century could be described as the age of automobiles. As a revolutionary product for travel and transportation, it transformed society, and grew into a giant industry that pulled up the economy and lead technological innovations. It was also the automobile industry that provided representative business models of the 20th century, such as mass production and the multi-divisional form of a corporate organization.

Needless to say, the importance of the automobile industry in Japan has been quite extensive. Especially after the oil shock, Japan established itself as the world's largest automobile producer, and introduced new business models like the "lean production system" or the "Toyota production system" to the world.

As we have just entered the 21st century, there are some indications for structural changes in the automobile industry. Ideas for new products with standardized parts that can be easily mixed and matched as in a PC, continuous M&A of automobile manufacturers over international borders to become industrial giants, competition in the development of new power sources such as the fuel cell. These are all possibly radical changes outside the realm of tradition. The Japanese automobile industry, which was once regarded as a formidable contender, also cannot help itself from being caught up in the worldwide wave of restructuring.

Will automobiles change? Will the structure of the industry, as well as the rules of the games and its players, be reformed? Which factors will change and what will stay the same? What will be logic behind these discontinuities and continuities? A balanced and systematic analysis is needed, one which is not superficial, but built upon the characteristics of the automobile industry. With such questions and aims in mind, this paper will focus on the environment and issues surrounding Japanese corporations. First, we will review the basic characteristics of the automobile as an industry and as a product, and then explain what the Japanese automobile industry has achieved. Based on this, we would like to look at the current trend of the industry and its competition, and finally comment on the future directions.

1. THE AUTOMOBILE – CHARACTERISTICS AS A PRODUCT AND AS A INDUSTRY

1.1 The Characteristics of the Automobile as a Product

1.1.1. The Functions and Issues of the Automobile

Both society and our daily lives have changed dramatically with the birth of the automobile. As a product, an automobile is required to have multiple functions. The very basic function is to move freely from point A to B, whether it is for transport or as a method of transportation. However, in many cases, the consumer today is not simply be satisfied with this. For instance, it has a symbolic function as a method of self-expression. Further, the automobile is seen as an individual's "toy," especially by the younger generation. In a way, the automobile can be considered as the greatest "toy" of the 20th century. At times, it can even function as a one's shelter or home. So, the automobile is required to function in various ways simultaneously. Technological innovations are necessary, but the most important point in producing marketable cars is the consistency of the message delivered to the consumers, or the overall "product integrity."

The diffusion of vehicles (7 billion worldwide) has also had adverse effects. With it came car accidents, noise pollution, and air pollution, all of which have become disturbance factors in public space. Automobiles definitely serve as a societal benefit, but at the same time, finding solutions to lessen their negative aspects will be an everlasting theme.

1.1.2. Technological Characteristics

Generally, the basic design plan consists of dividing the product into different parts, allocating the various functions to them, and deciding how to connect them (interface). This is what we call the "architecture." There are two dimensions for the architecture. One dimension comes from the product level, represented by the "modular architecture," a simple type with a comparatively standardized interface, and the "integral architecture," with a more complex relationship of parts and functions that requires each of the parts to be optimally designed to achieve its overall performance. The other dimension deals with the relationship among corporations, consisting of the "open architecture" and the "closed architecture." The open architecture is along the same line of the modular architecture in the sense that the interface is standardized and that the system can be designed by mixing and matching different parts, but in the open architecture, this is carried out beyond the boundaries of a single corporation. On the other hand, in the closed architecture, it is done within a single corporation.

The automobile is a product with an integral and closed architecture. For instance, consider the driving comfort (ride) of a car. Delicate factors, like a minor difference in the geometry of the suspension, or whether the principle axis of the engine is slightly in front of or behind the axle, can greatly influence the overall character of the car. In order to function as a system, each part must be designed optimally in this type of product. Further, if Toyota is manufacturing the car, the car must basically be designed by Toyota. The parts used in the car will be optimally designed specifically for Toyota. Bicycles and PCs are quite different. Their final products can be produced by putting together gathered standardized parts.

In terms of structure, the automobile is a very complex mechanical product. It is made up of a large number of parts. Although it depends on the way you count, if you dissemble everything to nuts and bolts, you will ultimately end up with about 20,000 to 30,000 individual parts. Even though the use of plastic and aluminum parts has increased in the recent years, the automobile is basically a product made of over a ton of steel. In the same way, despite the large amount of electronics being introduced to automobiles in the recent years, the automobile is nevertheless a mechanical "machine" product.

1.2. Characteristics of the Automobile Industry at the End of the 20th Century

The automobile industry is one of the largest manufacturing industries of the 20th century. Currently, 50 million of these high-price products of over 100 million yen are being produced and sold per year worldwide. Needless to say, it is an industry that has a huge influence on the national economy. In Japan, a biggest automobile producer of the world, the term "10% industry" is often used. This refers to the fact that the auto industry is involved in 10% of all employment (including services and other related fields), volume of shipping, export, and investment. Since automobiles consist of a wide range of materials and parts, the automobile manufacturer is unable to manage all manufacturing processes on its own. The parts are made by a vast number of parts suppliers, well over 10,000. Currently, the majority of first-tier suppliers are large-scale businesses with over 1000 employees. On the other hand, most of the second-tier suppliers who provide parts to the first-tier suppliers are typically medium and small-sized businesses with 50 to 100 employees. Further, the third and fourth-tier suppliers who provide parts to them are very small-scale businesses with only 5 to 10 employees. We also mustn't forget the important role of electronic parts suppliers and material suppliers such as steel and plastics. All of these businesses together support the competitiveness of the Japanese automobile industry.

As you can see, the influence of this industry is far-reaching, and, as a result of its extensive effect, it has been positioned as a strategic industry in many countries. Sometimes, the industry even symbolizes the nation's prestige. Interestingly, this industry is viewed as a kind of a "nation-owned capital." So if a large corporation were on the verge of bankruptcy in a certain country, it would be likely that the government would choose to offer help. In the US, for instance, when Chrysler was about to go out of business in the late 70's, in the end, the government took measures to save the company. There are a number of similar cases observed in Europe as well.

1.3. The Characteristics of Competition in the Automobile Industry

Until now, the automobile technology has advanced in a comparatively stable manner. In the recent years, there have been no great revolutions that brought a drastic change to the existing structure of the industry. The basic principle has been a slow and steady "cumulative progress." So far, there have been no revolutionary changes like that of the computer industry (i.e. the absolute champion, IBM and it's collapsing fortress). To say the least, there hasn't been any dramatic change where the game suddenly ended, with a new game starting with players you didn't even recognize. The slow and steady "industry marathon" is still on.

The competition in the auto industry is not dramatic, but is nevertheless severe. US, European, and Japanese auto manufacturers run neck and neck to unfold keen competition. Of course, competition is not completely open in the automobile industry. Burdened with national prestige, trade friction and managed trade are always an issue in the auto industry. However, the ground for intense competition amongst corporations within the industry does remain. Compared to other industries, such as the currently controversial field of finance, the automobile industry has been comparatively open to competition. This does not suggest that we have the competition as defined in economic textbooks. In reality, competition, cooperation, and conflict are mixed in a complex way.

At the product level, 20 to 30 auto manufacturers are fiercely competing worldwide. However, at the same time, many manufacturers establish partnerships locally to complement for their respective weaknesses, in the form of joint development, joint production, or technological tie-ups. In this industry, there is no strong move towards oligopoly by a few auto manufacturers, or the formation of regional blocks through protected trade. Instead, it has been a simultaneous mix of the three modes, which are cooperation, competition, and conflicts such as trade friction. (Fujimoto 1984)

2. OMPETITIVENESS OF THE JAPANESE AUTO INDUSTRY: INTERNATIONAL COMPARISON OF PRODUCTIVE PERFORMANCE

2.1. The Competitive Performance of the Japanese Auto Industry

The number of automobiles produced domestically in Japan equals to about 20% •approximately 10 million cars• of the total worldwide production. Since 1981, Japan surpassed the US, and became the number one auto producer in the world. After reaching the peak volume in 1990, domestic production has been on the decline, and the US has taken over the number one position for the time being. However, 20% of the total number of automobiles produced in the US is by Japanese manufacturers. When we include productions by such overseas production plants, the total production volume of Japanese automobile makers is estimated to be steady at about 16 million. (Figure 1)

If we list up the top 20 auto manufacturers in the world, 9 companies or about a half consist of Japanese manufacturers. Japan's auto industry is characterized by both its overall presence and the existence of the vast number of auto makers. It is fair to say that the keen competition of Japanese manufacturers, both inside and outside Japan, has been the driving force for development. Currently, some Japanese automobile makers are experiencing a tough situation with business operations, as a result of the decline in domestic sales and production. Due to the continual decline in some measures such as profit and stock prices, some companies have come to accept capital participation or the introduction of management personnel from overseas manufacturers. However, there are many manufacturers who have been able to maintain their strength, including those who have, in part, accepted capital participation. As we will observe, the fundamental operational capabilities (product development, production, and supplier system), which have supported the competitiveness of the Japanese auto makers, is still sound, and many overseas manufacturers still have the willingness to learn from such aspects of the Japanese makers.

2.2. Japanese Production, Development, and Supplier System: The Lean Production System

2.2.1. "The Lean Production System"

The production, development, and supplier system often referred to as the Toyota system, or "the lean production system" (an "ideal type" based on the "Toyota-style production system", though considerably simplified), was a key factor for Japan to establish its position as a top-class auto industry in the world.

The following is a list of the elements of the system:

- In production, many of the following features are combined: "just-in-time" (JIT) to suppress inventory, "kanban" system, total quality control (TQC), "jidoka" (automatic detection of defects and automatic shutdown of machines), "heijunka" (levelization of production volume and product mix), "genryo seisan" (production plans based on dealers' order volume), reduction of setup change time = small-lot production, mixed model production, one-at-a-time production, multi-skilled workers, "takotei-mochi" (multitask job assignment along the process flow), "shojinka" (flexible task assignment for volume changes and productivity improvement), "tsukurikomi" (building-in quality) through self inspection, "poka-yoke" (foolproof prevention of defects), "andon signboard" (real-time feedback of production troubles) with line stop cords, 5-S on the shop floor (cleanliness, order, discipline) , frequent revision of standard operating procedures by supervisors, self preventive maintenance through TPM (total productive maintenance), U-shaped layout, low cost automation, etc..(Ohno [1978], Shingo[1980], Nihon Noritsu Kyokai [1978], Monden [1983] [1993])

- Product development is characterized by the following features: strong project leaders (heavy-weight product manager) with the ability to create as well as actualize concepts, simultaneous engineering during development, a small team of top notch multi-skilled engineers, rapid production and maintaining quality of prototyping and dies and tools manufacturing, participation of parts and material manufacturers in the development process (design in). (Asanuma [1984], Asanuma

[1989], Clark and Fujimoto [1991], Fujimoto [1994])

- Supplier system is characterized by the following features: a higher level of outsourcing, multi-level suppliers, long-term, stable transactions, comparatively small number of large first-tier suppliers, subassembly delivery by first-tiers, design in, competition by design and improvement capability, continuous reduction in parts prices, elimination of receiving inspection, technological instruction and factory visits by assembly manufacturers. (Asanuma [1984], Cusumano and Takeishi [1991], Nishiguchi [1994], Fujimoto, Sei, Takeishi [1994], Fujimoto [1995])

The Toyota system with the above characteristics has the following competitive capabilities.

- Overcoming trade-offs: In manufacturing it has achieved competitive advantage simultaneously in production process productivity, manufacturing quality, production lead time; in product development it has achieved competitive advantage simultaneously in development productivity, design quality (product strength), and development lead time.

- Flexibility: It has achieved a flexibility to dealt with changes in products and the variety of products (variety in product mix, some fluctuations in total production volume, model change) with minimal increase in costs.

- Organizational learning and improvement: It has built-in organizational learning mechanisms that enhance productivity, improve quality, as well as solve other problems in manufacturing, continuously and on a company-wide scale.

These capabilities in production, development and purchasing systems contributed to the superior competitiveness of Japan in terms of productivity, manufacturing quality, productivity and speed of product development, product quality, cost and quality of parts. For instance, the International Motor Vehicle Program (Womack, et al, 1990) reported that companies that introduced the "lean production system" in some form or another marked a significant superiority in international competitiveness in the mass market of the auto industry during the 80's. The prominent mechanisms and the success of this system were well recognized by European and US auto and parts manufacturers, and they made efforts to learn from it and to catch up since the late 80's. As a result, the gap in many measures between Japan and Europe / US is decreasing

(Figure 2, Table 3). However, at the same time, Japanese manufacturers are continuing to improve, thus allowing the Japanese corporations to keep their leading positions in most of the indexes.

2.2.2. The Information Aspect in the Toyota-style Production and Product Development Capability

What is the mechanism behind Japan's system, more specifically, the Toyota-style system? If we look at it as an information creation-transmission system, where product-design information that carries value to the customers through the firm's productive resources, we may explain its competitive functions and structures in a coherent manner. While details can be found in Fujimoto (1999), a brief explanation is as follows. First of all, it is a system built-in with a rapid problem-solving cycle to constantly enhance competitiveness. Further, the total system allows value-carrying information to flow smoothly and constantly in both vertical and horizontal directions, making the amount of value-carrying information transmitted to the market more dense. In addition, as a result of the tightly knit flow of information, the market needs are translated into a concept, which in turn is articulated as the blueprint of the design, creating a development system that can make an accurate translation of market needs into the product.

For instance, one place you can discover the mechanisms of this system is the cut in inventory through "just-in-time". An inventory is a situation where the materials and work-in-process aren't receiving any value-carrying information from the manufacturing process (e.g., workers). Therefore, by reducing this, the information receiver in the manufacturing process (i.e., works-in-process inventories) will go through the production process more quickly. The key point is that the information sender (e.g., a worker or a machine) is unable to transmit information smoothly due to the above restriction on the side of the information receiver, causing a greater tendency for workers or machines to stagnate. This is precisely what is called the "muda" (non-value-adding time) of waiting.

By making the non-value-adding time visible, a problem solving cycle to improve productivity could be activated. Such methods as "visible management" by "Andon," or "neatness and order," also help problems come to the surface. More important, by repeating these improvement cycles, the employees will become much more predisposed with an "attitude to reveal manufacturing problems" so that they won't even overlook the slightest opportunity for improvement.

Once a problem is identified, the shop floor-initiated problem-solving cycle begins. This would include the revision of working standards lead by the shop floor supervisors, improvement proposals from individual workers, and small group activities. As a result, everything from cause detection, planning and evaluation of an improvement proposal, and the actual enforcement of the improvement plan are all quickly handled at the shop floor level. In drawing up the improvement plan, the wide spectrum of duties allotted in forms of “takotei-mochi” (flexible task assignment) and multi-skilled workers, makes it easier to implement fine-tuned redistribution of work assignment, thereby reducing non-value-adding time and increasing the net working time (information transmission time). The reorganized working formation is quickly incorporated into a manual as the new working standard, and is fixated within the working formation. Then, this starts a new problem improvement cycle. The basic principles are the same for production quality. It is the problem-identifying process and the quick problem-solving cycle at the shop floor level, which make the fast-pitch quality improvement possible.

As you can see, one of the characteristics of manufacturing companies like Toyota with strong competitiveness is that there tends to be an uninterrupted transmission of value-carrying information from the manufacturing process (e.g., worker) to the works-in-process. In addition to this, the feedback information constantly flows both downstream and upstream, urging the sender to transmit information that is easier for the receiver to cope with in the first place (e.g., design for manufacturing; DFM). Further, in the case of a development system, in addition to creating and processing information in a speedy and efficient way, heavy weight product managers (HWPM) and compact and competent project teams exchange detailed product information, resulting in highly integrated product design information, which is then accurately converted into information stock for the manufacturing such as production processes, and jigs and tools.

Although the elements of a development/production system may seem like just a collection of detailed routines and small techniques at a glance, a consistent pattern exists when you look at it from the perspective of information creation-transmission systems. Overall, this is a worthy competitive strategy. Further, since these “hidden production strategies” do not stand out by themselves, it is all the more troublesome for competitors who might have suddenly find themselves fallen behind only when it was too late. In the 1980's when the strong international competitiveness of Japan was recognized, it took a long time for American and European corporations to do a "counter catch up" against Japan, and yet Japan is still "ahead", These facts suggest that such quiet efforts to build up competitive capabilities as a complex information system could be a valid competitive strategy in the long run.

3. TRENDS OF THE 1990'S: "AGE OF GROWTH" TO "AGE OF FLUCTUATION"

Until the early 1990's, the Japanese auto industry was a leading figure with strong competitiveness backed up by the lean production system. However, it gradually began to slow down in the 90's, and some companies even fell into crisis. What happened in the 90's? On the large, two points can be pointed out: 1) the problems carried by the lean production system itself, 2) the gap in terms of strategic management (strategic initiatives of European and American corporations vs. the weakness of Japanese corporation in strategic management)

3.1. The End of Continual Growth and the Realization of Problems

The traditional lean production system, as noted earlier, was a superior system in itself, but it was in part dependent on the growth (increasing production) that was enjoyed throughout Japan for about 30 years. The stagnant domestic demand and the limitation of exports together brought an end to the "age of growth," and hidden problems began to surface at the same time. This was considered to be due to various "imbalances."

One example is the imbalance between the traditional product competitiveness (consumer satisfaction) and the somewhat lacking attractiveness of the production working site (employee satisfaction), or in more broader terms, the relative dissatisfaction of the stakeholders surrounding automobile manufacturers, including employees and the local community. This was allowed for a long time because the stakeholders were able to receive a share of the corporation's growth if the corporation concentrated on strengthening competitiveness and customer satisfaction. However, when growth stopped, this was not the case. Especially with the continuing trend of shorter working hours and decrease in young labor force, the current production line relying on a labor force of young men will need to be reformed. It has become critical to improve the attractiveness of the working environment, such as making the work place more attractive for female and older workers, changing the working hours, introducing automation to reduce physical strain, and reforming works process and actual work design. In addition, the satisfaction of the general society, suppliers, community and shareholders will also need to be improved.

Second of all, there is the imbalance between the "lean, efficient production and development system," represented by the Toyota-style production or TQC, and the "fat in product design, plant design, and distribution system," a hidden problem that was not traditionally taken up as an important issue. A new system is needed that can generate cash flow and maintain competitiveness, even during periods of reductions in production. The task is to renew the corporation's predisposition to a balanced and lean type, for example, by simplifying the product design itself that tended to be over-excessive (cutting variation, increasing common parts, value engineering retracing the original plan, etc.), lowering costs of plant designs which tended to be excessive in terms of technology, method, and facilities during the recent years, and simplifying the framework of the domestic distribution system which was supported by huge sales promotion budgets in the form of discounts and rebates.

However, simplification is not the same as just going back to "cheap and low quality," since this will not satisfy the well-educated consumers and employees of today. Simplification of product design, simplification of plant design, and reconsideration of discounts and rebates must be done by maintaining a high level of customer satisfaction and employee satisfaction at the same time. Again, the effort to consider the balance of the total system will become the key factor.

3.2. Switch to a Balanced-Lean Production System and Capability-Building Competition

3.2.1. Switch to a Balanced-Lean Production System

If the age of continual growth lasting for 40 years since the end of WWII has moved on to an "age of fluctuation" repeating increase and decrease in production, it becomes necessary to switch to a balanced system fit for the 21st century by reforming portions which had previously assumed continual growth of production and supply of young male labor force, while maintaining traditional strengths (Fujimoto and Takeishi 1994).

Although differences do exist amongst corporations, Japanese auto makers are taking steps towards reform to recover their balance.

At the production site, more weight is being placed on the satisfaction of workers, and the production line itself is being reconsidered so as to improve ergonomics and to attach significance to each individual's work. New steps, like extensive recycling and decreasing industrial waste, are being taken as environmental measures, to improve the balance of "lean" and "green." For instance, if you visit Toyota's production plants, you would find drastic changes compared to 10 years ago, in terms of "environmental measures" and "human-oriented consideration."

3.2.2. Capability-building Competition in Product Development

While recovering balance, Japanese makers are also working on capability building to further strengthen its lean production system. As an example of forefront capability-building competition, let us look at the trend of shortening product development lead time. The minimum development period said to be 30 months from the design fix, has been cut down to 20 months, or even less, by some companies in Japan. They are making a spurt to move ahead since the US and Europe have begun to catch up.

The leading contributor today is called front-loading, or "problem-solving at an early stage" so to say. To be specific, it tries to solve as many problems as possible before the first prototype car is made. For the time being, the goal is placed at about 80%. To achieve this, 3D CAD-CAE, early design review, and a type of knowledge transfer that make the most of experiences from previous projects are combined together to solve 80% of the problems before the first prototype is made. Therefore, in this approach, most problems will already be solved by the time the first prototype is completed.

In front-loading, what becomes important obviously is documenting the reflections of previous projects and to transfer this information. But in reality, this is difficult to carry out. It is said that this seemingly easy task will remain as a challenge, including the difficulty of communication between people. Certainly, an extremely great change is occurring on the surface with the introduction of 3D CAD and CAE, but none of the fundamental principles behind it have changed at all. For instance, despite the major advancement in information technology, the importance placed on early and integrated problem-solving has not changed since the 70's. The reason is because this industry is a world of closed architecture that requires integrated problem-solving.

3.2.3. Overcoming the Fluctuating Volume

In a production system, the biggest issue is how to overcome the influence of volume. There is a continuous struggle for a processing/assembly line that can cope with fluctuations in volume. The traditional lean production system had been successful in terms of its flexibility, model mix, and ability to produce many variations both efficiently and of high quality, but there were no effective measures against large-scale fluctuations in the total production volume itself. The question is how to minimize the minimum-optimal scale (the minimum production quantity which meets the long-term average cost to withstand competition), often said to be 200,000 automobiles, as much as possible. Both domestic and overseas, new production plants will be designed to test whether it can profit with annual production of less than 50,000 automobiles through various mechanisms such as simplifying machines and jigs and making them more generic to be used for different models, shortening production processes, and multiple-line methods. In this way, at the forefront of capability building competition, there is a continuous effort by each company to minimize the negative impact of volume changes, and in that particular point, Japanese makers are generally ahead of others. They are trying to acquire the capability to cope with the decrease in volume on one hand, while longing for the recovery of volume on the other.

3.3. The Strategic Challenges of US and Europe vs. Japan's Weakness

While Japanese manufacturers are making progress in partially revising the lean production system and in building new capability, European and American auto makers have also overcome the sluggish economy and crisis of the 80's, and have gradually regained their vigor back by the 90's. No doubt, learning from the lean production system and the "counter-catch up" through its application have contributed to the recovery of the European and American auto industries. America's Chrysler and France's Renault, who've overcome their crisis, have studies the Japanese system closely, applied the framework, and lead to the recovery of their business results.

However, this explanation only accounts for a part of the European and American recovery story. As pointed out earlier, although the gap has shrunk, there has been no turnaround. Japanese corporations are in many ways still ahead in the capability-building competition. Not everything can be explained with the "counter-catch up" hypothesis.

3.3.1. Architectural Strategy: US Light-Truck Business

In understanding the success of American auto makers, “architecture” specifically becomes a key factor. The automobile is a product with closed integral architecture. However, this does not necessarily apply to trucks, which somewhat have the characteristics of an open architecture. In terms of architecture, the American auto industry has traditionally been like a truck maker dating back to the Ford Model-T, using the body-on-frame method that places the body on a ladder frame, even for passenger cars.

When the truck-type architecture became invalid from the second oil shock, they switched to the Japanese and European-type architecture called the monocock body (forming the automobile as a box made of 0.8mm steel, and increasing its strength as a whole box). However, since the American manufacturers had little experience in this architecture, sedan-type passenger cars ended up having poor product quality between the early and mid 80’s. Whether it was done on purpose or not is unknown, but the next strategy they took was the extremely clever way to reverse the American auto market into a one centered on trucks.

From the mid 80’s on, the share of RVs (minivan, sports utility vehicles, pick up trucks, etc.) grew in the US, but, unlike Japan, many RV’s made in the US were truck-based. Due to historical circumstances, there is a 25% duty on trucks in the US market protecting it from import, and their frames can be mass-produced. Further, the profitability is quite high since the body can be exchanged like a dress-up doll, the price can be boosted by a luxurious interior, and development costs and sales costs are low. It also fits the taste of Americans who generally tend to love the outdoors and prefer larger sizes. In this way, the American market experienced a historical turning point where the number of truck-based vehicles sold surpassed that of passenger-car vehicles.

Now, the room left for Japanese makers skilled in sedan-type passengers is less than half of the US market. Although there are environmental concerns, strictly in terms of competitive strategy, we can’t deny that the US’s double-sided strategy of using its traditional truck-based business model and defending its truck market, while thoroughly studying Japan’s lean production method, is very prominent.

The former Chrysler that had the highest profitability per vehicle in the world, was also the most enthusiastic learner of the lean production system, and certainly succeeded to shrinking the gap for some indexes against Japan. However, most of their profit was actually generated by the truck division, and the profitability of their passenger car division is known to be inferior. Further, we mustn't forget the fact that the unprecedented boom of the US market in the late 90's supported the good conditions of US manufacturers. If we ignore the difference in the field of competition as well as in environmental conditions, and simply try to evaluate the capabilities of companies through differences in profitability, we may be lead to the misunderstanding that "the age for Japan to stand superior with the lean production has ended."

3.3.2. Attempts for Modularization

From the mid 90's, many auto makers, especially in Europe, have been making rigorous attempts to modularize their automobile production. Although it would be confusing, this is a different process from the architectural modularization that was discussed earlier. The modularization being advanced in the auto industry refers to sub-assembling parts in bigger units than done traditionally, and outsourcing this task to external parts manufacturers.

For instance, at the "smart car" production plant run by MCC corporation, a joint venture of Daimler-Chrysler and Swiss watch maker SMH, the suppliers, or system partners, stand in the adjacent area enclosing the MCC assembly plant, assembling modules such as cockpits, front ends, and doors. They directly supply MCC's final assembly line. Even the body-welding and body paint, traditionally in the domain of assembly manufacturers, are left to the hands of the suppliers. As a general trend, the idea of US auto manufacturers is also towards outsourcing the production and development of parts to suppliers in a broader scope.

It is pointed out that behind the increase in outsourcing is the target of auto manufacturers to take advantage of the relatively lower labor costs of the parts manufacturers, or to decrease the burden and risks of their own investment. The concept of more extensive outsourcing was originally taken from the supplier system and purchase management practiced by Japanese auto manufacturers, but the extent of using the parts suppliers has gone far beyond the level of traditional Japanese ways. There seems a crucial awareness of European auto manufacturers that the existing automobile business would be difficult to profit from. They are trying to build a new business framework that would increase profitability by making full use of suppliers. It is a kind of a challenge to compete with a new business model. However, at this point, the question still remains as to whether outsourcing more to suppliers would lead to higher profits.

To respond to, and also to accelerate, these trends of auto manufacturers, an increasing number of parts manufacturers in Europe and US are experiencing mergers and acquisitions within the industry. By acquiring and merging with parts manufacturers producing related components, they attempt to establish themselves as module suppliers.

Also in Japan, at the assembly plant level, the expansion of the subassembly line is being advanced to increase the satisfaction of workers,. However, there is no strong intention of expanding the scope of outsourcing to parts manufacturers compared to traditional levels. The reason for this is that the advantage of outsourcing is still vague, and that they tend to dislike the “technological hollow-out”.

Since automobiles are integral architecture products, it is difficult to simply divide them into several sub-systems, and outsource each sub-system’s entire development and production process to a supplier. To enhance modularization, it is necessary to transform the architecture into a more modular type. However, whether the consumers will be willing to accept this is still unknown. For the time being, trial and error should continue in the modularization of the auto industry.

3.3.3. The Weakness of Japanese Corporations in Strategic Management

The revival of American and European corporations in the 90’s did not simply happen by learning from the lean production system. It was all centered on top-down strategic initiatives, such as the offensive based on light trucks, and the drastic attempts for modularization, although the result of the modularization does remain unclear. Compared to that, although Japanese auto makers still have superior results in strengthening basic capabilities for production and development, they are falling behind in creating strategic frameworks that lead to enhanced competitiveness or higher profit, or in taking actions to quickly overcome structural problems. It is the weakness in strategic management.

The growth period for Japanese auto manufacturers has ended, and we have entered the age of fluctuations. This situation has precisely revealed the strategic inexpertness of Japanese makers. During the age of growth, strengthening basic capabilities lead to a desirable outcome. The target was clear, and the strategic pillar was to concentrate on strengthening basic capabilities. However, with an end in growth, it was necessary to cut back and restructure the excessive production capabilities, product line-ups, distribution channels and the like. They have to decide, in a strict manner, what to keep and what to throw out, making evaluations for investment priorities with limited resources. Yet, some auto manufacturers were unable to make these strategic management decisions due to organizational inertia and weirs as well as attachment to past success, and simply put off necessary decisions.

If we look at the case of Ford's bolstering of Mazda, Mazda has implemented the ways of strategic decision-making from Ford (e.g., clarifying responsibilities, stressing facts and logic in the decision-making process). This has clearly contributed to the recent revival of this company (Nobeoka and Taniguchi, 2000). The same kind of pattern can be seen in the capital alliance of Nissan and Renault, in which Nissan has been learning the ways of strategic decision-making from Renault.

Of course, not all Japanese auto manufacturers are incapable of strategic management. There are companies maintaining superb performance by streamlining their product lines. There are also companies leading the world with automobile technologies of the next age, such as hybrid cars. There are also moves to launch products in the US light truck market as an offensive measure to the money box of the US makers. However, generally speaking, strategic management is not exactly the strong point of Japanese corporations when compared to American and European corporations. We have moved from the age of growth to the age of fluctuation, and there are also possibilities for new technological innovations (will be discussed in more detail later). Facing much uncertainty for the future, it is the challenge for Japanese companies to improve the quality of its strategic planning and decision-making, which is getting increasingly important.

3.4. The Worldwide Reorganization of the Auto Industry

3.4.1. Reorganization Rush

At the end of the 90's, mergers, acquisitions, and capital alliances became quite active amongst the auto manufacturers worldwide. Actually, since the 70's, there have been forecasts that the number of auto manufacturers worldwide would eventually come down to 8 to 10 companies, a view which has been taken up by the media as well. However, in reality, nothing really happened on a large-scale, with the exception of some cases in which major corporation bought small-scale luxury auto manufacturers. What happened instead, as one of the authors foresaw (Fujimoto 1994), was the significant increase in alliances between different auto manufacturers. The number of partnerships amongst auto manufacturers was about 40 in 1985, and increased to over a 100 by 1990. Since then, through partial changes and additional alliances, the number of alliances has remained more or less stable. As a result, the worldwide auto industry is now covered by a seamless but comparatively loose alliance network (Table 4).

We have not observed, on the other hand, significant decrease in the number of automakers who are financially independent (not a subsidiary whose majority of stocks is owned another OEM), manufacture the body and engine on their own, and have their own brand name and distribution channels. In 1980, there were 30 of such auto manufacturers. This decreased to 27 in 1990, and to 24 in mid 1998. Although it is gradually decreasing, there is no extensive oligopolization.

However, starting with the merger of Daimler-Benz and Chrysler in October 1998, the trend of acquisition and capital alliance quickly accelerated throughout the world (acquisition of Volvo by Ford, and capital alliances of Renault and Nissan, GM and Fuji Heavy Industries, GM and Fiat, and Daimler –Chrysler and Mitsubishi Motors). The argument of “a worldwide rapid move towards oligopoly” suddenly surfaced again.

3.4.2. Pursuit of Volume

One foundation of the oligopolization theory is the argument that in pursuing the advantages of quantity, large mergers are the inevitable result. We often hear “4 million productions of cars are needed per year for survival.” This reflects the emphasis placed on the advantages of quantity.

Of course there is a certain amount of truth in these theories of “large-scale equals strength.” Well known are theoretical concepts like “economies of scale (increasing return on scale)” and “externality of a network (higher customer satisfaction with increased number of a product’s users)” and the empirical evidence like the “Silverstone Curve (demonstrates the relationship of expansion in production scale and decrease in costs in automobiles)” and the “Experience Curve (demonstrates the relationship of increase in cumulative production quantity and decrease in costs)," to name a few. However, none of these lead us to the conclusion, "4 million car production per year is needed for auto makers to survive." Generally, the smallest optimum mass production scale for automobile production is said to be about 200,000 to 300,000 cars per platform. For instance, even if we assume a company needs 5 platforms to stabilize its entire business, 1 million to 1.5 million would be more than sufficient. In fact, there are many companies who are doing well on a similar scale.

Then, how did they come up with this mysterious number? It is probably a simple division of the current world market of 50 million plus vehicles by 10 corporations (although there is no reason in this itself), which comes out to 4 to 5 million plus vehicles per company. Or it may simply be the reverse, trying to fit the fact that the top corporations currently all produce 4 million plus vehicles. If you want to join the top group through quantity, clearly this type of large-scale production is needed. However, from there to "4 million cars for survival" is an extreme jump of logic. In order to secure the mass production scale of products or parts, it is much more efficient to take a alliance strategy, so that you can choose your best partner flexibly according to the particular model or location. The argument of producing 4 millions vehicles through mega-mergers is hardly persuasive. In reality, many facts are against the theory of "large-scale equals strength." For instance, take a look at GM, the world's largest auto maker. Why is their competitiveness and profitability not outstanding? On the other hand, take a look at Honda, Fuji Heavy Industries, and Suzuki. Why have they done comparatively well in a sluggish economy?

3.4.3. Technological Supremacy

The other convincing theory is as follows. "There are only a few auto makers in the world which can deliver the technologies for the 21st century like the post-gasoline engine, all on its own. Only a very few giant companies can win this struggle of supremacy." This is a world oligopoly theory based on technology investment and technological supremacy. Companies capable of developing new technology may certainly be just a few (most likely Benz, GM, and Toyota will be included here). Rather, preparing for the coming age of fuel cell automobiles and post-gasoline technologies, companies that currently don't assemble cars (for instance, electronics or automobile parts manufacturers) may lie in ambush. At any rate, it is doubtful that all 20 to 30 companies which actively participate in the world market today will have such technological development capabilities on their own. Through mega-mergers, a company can secure its funding capabilities to invest vast amounts of money to developmental research. Further, a larger corporation could gain advantage in terms of political influence on environmental regulations and in establishing networks with important suppliers, enhancing the possibility to precede others in undertaking future-generation automobiles.

However, even if this was the case, there is room for arguing whether it is necessary for companies of different types to actually merge together, simply to win the race for technological standards. Winning technological standards does not require a strong and fixed partnership of a merger. It may be wiser to achieve this through the flexible use of a strategic alliance. It may be easier to find collaborators in an alliance-based approach. Further, it would not necessarily be the best plan to limit your partners through mergers in the continuing process of dynamic technological innovations. Alternative choice available is to establish a network based on technological alliance, instead of a unreasonable merger to proceed with cooperative developments, or make money through "licensing" innovative technologies to other companies. It would still be too premature to conclude that the auto industry has reached the age of oligopoly dominated by a few giant companies. (Fujimoto, Takeishi, and Nobeoka 1999)

4. PROSPECTS OF THE 21ST CENTURY: "MODE OF EVOLUTION" FOR THE FORESEEABLE FUTURE ??

4.1. Automobiles of the 21st Century: Technology, Architecture, Information Technology

4.1.1. Shall We Have De-maturity?

We haven't experienced technical innovations radical enough to overturn existing industrial structure (de-maturity) yet, despite the possibilities of its happening. For example, around 1980, the price of gasoline spiked due to the oil shock in the US. Assuming that this "marked the end of the gasoline age, and a totally different type of engine, although it was still unknown, such as gas turbines, steam, or electric automobiles, would emerge as the dominant design in the future," a vast investment was made during the Carter administration. However, this was a strike at the air. Existing technologies (the current champion) are often quite enduring than you would expect. 20 years later, gasoline automobiles made of steel are still mainstream, and de-maturity (being taken over by a new champion) did not take place.

However, we do not know precisely how the situation may change in the first half of the 21st century. For example, in a long-term perspective, of say 30 years, full-scale motorization may occur in heavily populated China, India, and in the entire Asia region. Then it will be necessary to make twice as many vehicles produced in the world today. In such cases, it will be impossible to lean completely on gasoline automobiles as we do now, both in terms of the limited energy source and environmental issues.

4.1.2. The Future of Engines

There are many possibilities as how future engines will turn out. For instance, the diesel engine will need to hold down the soot and smoke that effect the surrounding environment, but its energy efficiency is an attractive factor. On the other hand, gasoline engines are gradually being improved in many forms like lean-burn and fuel direct injection system. Further, a car combining the features of the gasoline engine and the electric car is already being sold in Japan as the hybrid car. It is said that this may improve the energy efficiency by twice. This means the amount of carbon dioxide produced will be reduced to half. It looks like Japanese manufacturers are leading the world technologically in the field of improved gasoline engines and hybrid cars.

Against this, the electric car itself, using rechargeable batteries, is being improved. The typical electric car had a normal lead battery of about 500kg placed under the car floor, but recently, new high-powered types like the nickel hydrogen battery have become available. The problem lies in costs. Since the materials are expensive, the car will be far more high-priced than a gasoline car, even if it were mass-produced. In addition, there is the question of where to generate the electricity used for recharging the batteries in the first place. If we use the thermal power generation, carbon dioxide will be produced, so it won't be zero carbon dioxide. Based on the current pattern of generating electricity in Japan, it is estimated that 60% of the carbon dioxide production would be cut down through the use of electric cars. However, hybrid cars are also estimated to bring a 50% cut down, which is not a significant difference. In fact, the crucial point becomes how much carbon dioxide is produced in generating electricity.

Further, we expect fuel-cell automobiles to come into existence in the future. In short, it's like reversed electrolysis, making water with hydrogen and oxygen, and generating electricity in this process. Therefore, it does not need to be recharged from the outside. The problem is how to make hydrogen, and there are still many technical issues to be resolved. However, there is also anticipation that it will be one of the prospective winners in the first half of the 21st century. By 2030, it may possibly become a product that rivals gasoline automobiles.

Will gasoline cars completely disappear as a result? No, that will probably not be the case. However, we can expect a change from the complete dominance by gasoline cars to a bit more balanced mix of engines.

4.1.3. Will Automobiles Become Open Architecture?

The first question is whether the design of automobiles can become "open." In other words, would it be possible to make automobiles by gathering widely used standardized parts as in a PC or a bicycle? Standardizing the interface of parts will become the key factor, and this definitely can't be achieved through the existing method of manufacturing gasoline cars with steel plates. However, there may be a shift to a more "open" architecture, with the coming age of electric cars.

The second point is automobiles becoming more open in terms of its information system. Currently, there is a new idea being developed, called the Intelligent Transportation System (ITS). For instance, the system will deliver traffic jam information through communication amongst cars, between cars and ground facilities, and between cars and roads. Or, it will adjust the distance between cars through automatic control, so that cars run on highways like train cars. It is said that if such measures are taken, traffic jams on expressways will evidently disappear. By increasing the average speed and decreasing traffic jams, the energy efficiency will greatly improve, and the amount of carbon dioxide emission will also be reduced. Improving the energy efficiency for each car is important, but cars need to become more "open" in its architecture so that it can take in external information. Further, if cars can communicate amongst each other, it could lead to the conservation of energy and solutions to environmental problems. In other words, automobiles can no longer continue to be an independent "closed" box. It will essentially become a single little piece in an entire system.

4.2. Auto Industry in the 21st Century: Excellence in Management Quality and Architectural Changes

4.2.1. The Focus of Competition on Management Quality = Capability

The driving force of the auto industry's advancement itself is, after all, a dynamic competition of the world's auto companies to build competitive capability, or in other words, competition of "capability-building." In the current world auto industry, the popular view of "the bigger the stronger" is getting rather pervasive, but as noted earlier, this argument seems to be off the real issue of industrial competition. Of course, it is easy to get the impression that we have reached the "age of size" due to the recent "one-winner" phenomena seen in the information industry, the mega-mergers in the financial industry, or the Daimler=Chrysler merger. However, it is precisely in such a period that logical actions need to be taken. The real issue is to compete in the "quality" of management, and quantity is simply an end product.

Here, "quality" refers to the competitiveness of the product as well as the competitive capability of the organization behind it. Further the real essence of global competition amongst automobile companies today is to compete in terms of organizational or management "quality," which in turn results in quantity based on quality. Therefore, we can say that it is indeed "a competition of capability building." In other words, the logic is not "quantity•power•quantity," but rather, "quality•power•quantity."

In that sense, the pitfall in the "myth of scale" is the complete mix-up of "achieving quantity as a natural consequence" vs. "pursuing quantity as a goal." The former is quite all right, but the latter is dangerous. If you try to extend your scale beyond the "quantity matched by quality," evidently it will not happen, and you will just end up with excessive inventory, production capacity, and debts. As a result, the products will be dumped with huge discounts, and the company will fall into a financial crisis. Wasn't this the exact pattern followed by those auto companies that fell into crisis in the recent years? Whether the Daimler Chrysler merger will really become a threat, as it is often said to become, still remains unknown.

Unless backed up by improved capability, superficial expansion of scale through mergers and increased percentage in capital contribution mean virtually nothing. Instead, if there is a mutual goal to "improve capability," a merger isn't really necessary, and a strategic alliance should serve just as well. In reality, the primary movement of reorganization in the auto industry during the last 20 years has been "a network of strategic alliances." In terms of number, mergers were secondary.

A wide variety of capabilities are needed, and the competition is fierce. One key factor is the capability of the automobiles to cope with its negative aspects. As mentioned earlier, an automobile is a product with many negative aspects like car accidents and environmental problems. Therefore, it must continue to try to lessen these negative factors eternally into the future. It must continue to innovate. In that sense, the automobile will keep evolving.

Further, efforts should continue to lessen the negative aspects of the automobile production process described as “boring, exhausting, dirty, and hard work.” In other words, the goal to decrease the negative aspects, both in terms of production and the automobile itself, is the driving force for the everlasting innovation. Building a production system that can withstand large volume fluctuations is also important. The current distribution system based on exclusive dealers with discounts taking place regularly is not efficient at all, and does not give sufficient satisfaction to customers. Although the effect of using the Internet is still a question, it is most certain that innovation in the distribution system is being awaited. At the same time, the positive aspects of the automobile, such as “fun and convenient” will be enhanced. There is no end to the capability building competition.

4.2.2. Industrial Organization

The majority of the cases may continue to consist of strategic alliances centered on capability building, but, at the same time, it is not a network that is on equal terms for all or would satisfy everyone for a long time. The picture certainly does not look that simple. What we can imagine is the following scenario. A stratified network will be formed and maintained by different types of auto manufacturers, including a relatively small number of leading auto makers with the development capabilities of the 21st century technologies, auto makers with their own distinct engine, body, brand image, and distribution network that depend on these technologies, brand name manufacturers who don’t make engines but make the body, and consigned assembly manufacturers. All of these companies will remain dependent on each other for technology or capital.

Therefore, the answer to the question as to “how many companies can survive” will depend on what you would define to be an “auto manufacturer.” If the question is how many auto makers will be genuinely independent with no alliance partners at all, the answer would be “zero.” There may only be a few auto makers worldwide who can be self-sufficient of the technologies necessary for the 21st century. However, as long as internal combustion engines are mainstream, there may continue to be about 20 to 30 auto makers with their own engine, body, brand, and distribution network (what we define as an "auto manufacturer") in the future. There may even be more "independent body manufacturers" who won't make engines but make the body and have their own brand name. These "body specialists" may continue to increase in the future with the coming age of electronic cars and fuel-cell cars.

At any rate, the scenario of a "network based on several technological centers" is much more realistic than "the world being divided by about 10 giant firms."

4.2.3. The Future of "Architecture"

When we think about the future course of the auto industry, the "architecture" becomes important in addition to "capability-building competition." This is because when the architecture changes, the whole foundation of the product also changes. As discussed earlier, there is a significant strategic importance in the small difference in architecture between trucks and passenger cars. There was a dramatic change observed in the computer industry that switched from the closed (mainframe computer) to open (personal computer) architecture. Based on the existing architecture, we do not know whether the ongoing modularization in Europe and US would even be worthwhile. However, if the architecture changes, it may change the inter-firm division of labor as well as the inter-firm distribution of the value-added. This issue requires the ability to conceptualize business models and strategic ways of thinking.

At the same time, auto manufacturers will continue to steadily pursue cumulative progress and capability-building competition. By doing so, these corporations should become more valued by various stakeholders, even respected in some ways, in the 21st century.

CONCLUSION

During the past quarter of a century, the Japanese auto industry was the leader in the world auto industry. It presented corporate management models like the Toyota system, or the lean production system to the world. However, the Japanese auto industry has begun to lose the momentum it used to have in the recent years. With the worldwide trend of reorganization, there are only two auto manufacturers (Toyota and

Honda) left without capital partnership with foreign auto manufacturers.

What is going on in the auto industry? Have the Japanese auto manufacturers lost their competitiveness? This paper has clearly identified that the Japanese auto industry is not inferior compared to Europe or US. Although Japan was behind in taking up strategic measures, it continues to lead the world in new capability-building competition through the pursuit of speedy product development and a flexible production system that copes with fluctuations in volume.

The goal of the Japanese auto industry is to further strengthen capability building that aims for better quality, and, at the same time, strengthen its strategic management to make the most out of the capability building. Strategic ideas and activities will become more and more important, especially, as the auto industry reaches a period of reformation characterized by new power sources, a more open architecture of automobiles, and changes in product architecture. Corporations will need to have a double-sided plan. On one hand, they will need to continue to steadily improve capability building without being fooled by superficial arguments, and on the other hand, they will need to undertake reforms more strategically and actively without losing sight of the overall trend.

REFERENCES

Asanuma, Banri (1984). "Jidosha sangyo ni okeru buhin torihiki no kozo" [Structures of Parts Transactions in the Automobile Industry]. *Kikan Gendai Keizai*, Summer: 38-48 (in Japnese).

Asanuma, Banri. (1989) "Manufacturer-Supplier Relationships in Japanese Subcontracting: A Microeconomic Study of the Automobile Industry," *Journal of the Japanese and International Economics*, 6, March: 1-29.

Clark, Kim B. and Takahiro Fujimoto. (1991) *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry*, Boston, MA: Harvard Business School Press.

Cusumano, Michael A. and Akira Takeishi. (1991) "Supplier Relations and Management: A Survey of Japanese, Japanese-Transplant, and U.S. Auto Plants." *Strategic Management Journal*, 12 (8): 563-588.

Ellison, David J., Kim B. Clark, Takahiro Fujimoto, and Young-suk Hyun. (1995) "Product Development Performance in the Auto Industry: 1990s Update." Working Paper 95-066, Harvard Business School.

Fujimoto, Takahiro (1984). "Sekai no jidosha sangyo wa kou kawaru" [Future of the World Auto Industry]. *Shukan Ekonomisuto*, August 28 (in Japnese).

Fujimoto, Takahiro. (1994) "Re-interpreting the Resource-Capability View of the Firm: A Case of the Development-Production Ssystems of the Japanese Auto Makers," Discussion Paper, Tokyo University Faculty of Economics, 94-F-20.

Fujimoto, Takahiro (1995). "Buhin torihiki to kigyo kan kankei: jidosha sangyo no jirei wo chushin ni" [Parts Transaction and Inter-firm Relations: The Case of the Auto Industry]. In Masu Uekusa (ed.) *Nihon no Sangyo Soshiki* [Japan's Industrial Organization]. Tokyo: Yuhikaku (in Japnese).

Fujimoto, Takahiro (1999). *The Evolution of A Manufacturing System at Toyota.* New York: Oxford University Press.

Fujimoto, Takahiro, Shoichiro Sei, and Akira Takeishi (1994). "Nihon jidosha sangyo no sapuraiya shisutemu no zentaizo to sono tamensei [Supplier System in the Japanese Automobile Industry: Its Entire System and Multifaceted Features]." *Kikai Keizai Kenkyu* 24 (May):11-36 (in Japnese).

Fujimoto, Takahiro and Akira Takeishi (1994). *Jidosha sangyo 21 seiki heno shinario* [The Automobile Industry: A Scenario towards the 21st Century]. Tokyo: Seisansei Shuppan (in Japnese).

Fujimoto, Takahiro, Akira Takeishi and Kentaro Nobeoka (1999). "Jidosha sangyo no sekaiteki saihen: Kibo koso subete? [Shake Out in the World Auto Industry: Is Volume All You Need?]. *Hitotsubashi Business Review*, Vol. 47, No. 2: 11-25 (in Japnese).

Monden, Yasunori. (1983) *Toyota Production System* (1st. ed.), Norcross, GA: Industrial Engineering and Management Press.

Monden, Yasunori. (1993) *Toyota Production System* (2nd. ed.), Norcross, GA: Industrial Engineering and Management Press.

Nihon Noritsu Kyokai [Japan Management Association] ed. (1978). *Toyota no genba kanri* [Shop Floor Management at Toyota]. Tokyo: Nihon Noritsu Kyokai (in Japanese).

Nishiguchi, Toshihiro. (1994) *Strategic Industrial Sourcing: The Japanese Advantage*. New York, NY: Oxford University Press.

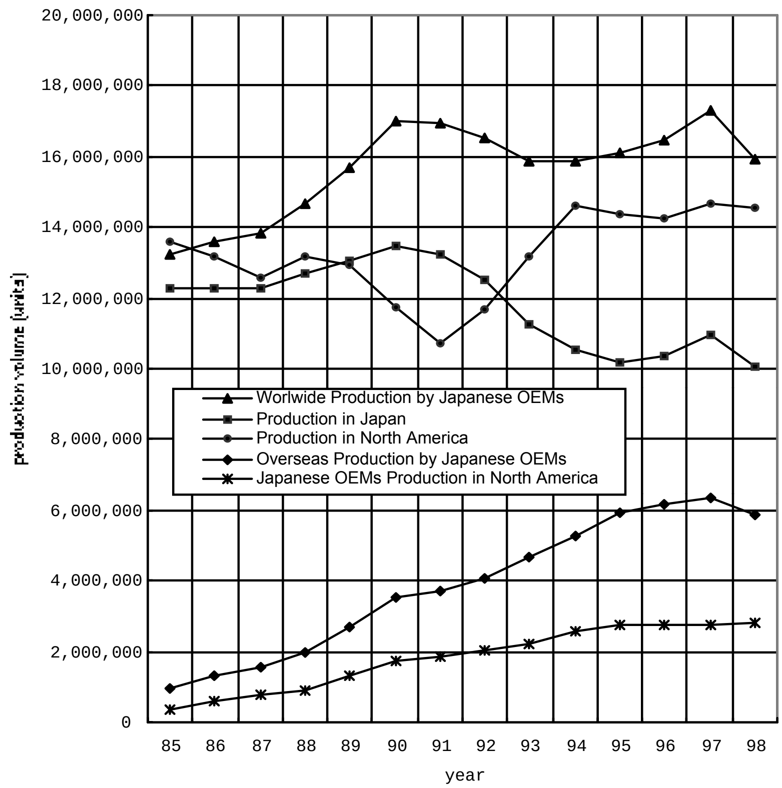
Nobeoka, Kentaro and Mami Taniguchi (2000). "Ishitsu no keiei no yugo; Ford shudou ni yoru Mazda no keiei kakushin" [Fusion of Heterogeneous Management: Mazda's Management Changes lead by Ford]. Discussion Paper #J29, Research Institute for Economics and Business Administration, Kobe University (in Japnese).

Ohno, Taichi (1978). *Toyota seisan hoshiki* [Toyota Production System]. Tokyo: Diamondo (in Japanese).

Shingo, Shigeo (1980). *Toyota seisan hoshiki no IE-teki kosatsu* [An Industrial Engineering Analysis of Toyota Production System]. Tokyo: Nikkan Kogyo Shinbunsha (in Japanese).

Womack, James P., Daniel T. Jones, and Daniel Roos. (1990) *The Machine that Changed the World*. New York, NY: Rawson Associates.

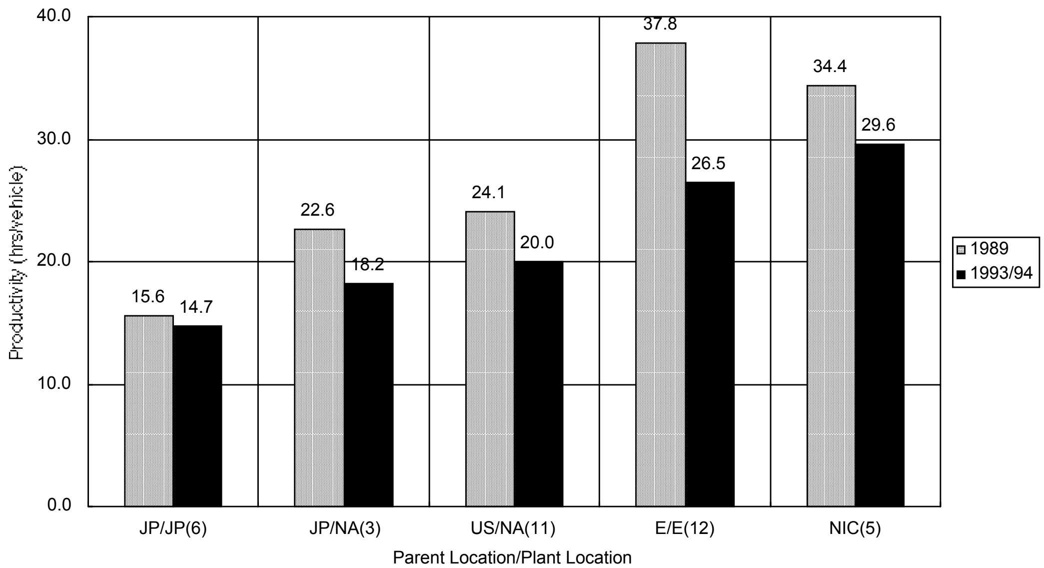
Figure 1: Automobile Production Volume:
Production in Japan and North America, and
Domestic and Overseas Production by Japanese OEMs



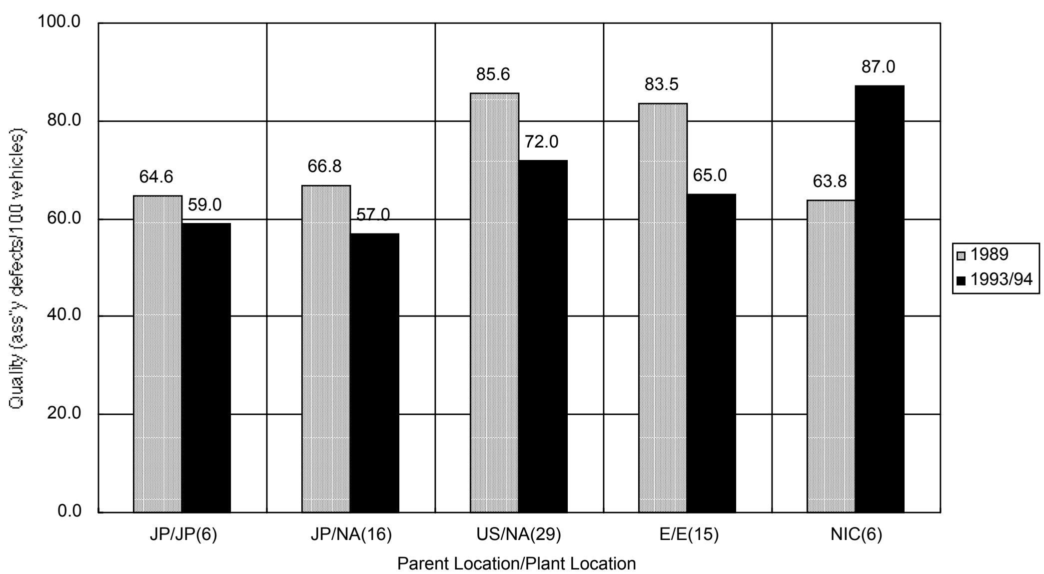
Source: Compiled from Japan Automobile Manufacturers Association, *Kaigai Shuyou Koku Jidosha Tokei* [Automobile Statistics for Major Foreign Countries].

Figure 2: Assembly Plant Performance in the World:
Productivity and Quality

(1) Assembly Plant Productivity



(2) Assembly Plant Quality



Note: JP=Japan, NA=North America, E=Europe, NIC=newly industrializing countries
Source: MIT International Motor Vehicle Program (based on the Assembly Plant Surveys conducted by J.P.MacDaffie amd F. Pil)

Table 3: Regional Comparison of Product Development Performance 1980s versus 1990s

		Japan	U.S.	Europe	Total
number of sample projects	1980s	12	6	11	29
	1990s	8	5	12	25
unadjusted total lead time (mo.)	1980s	43	62	61	53
	1990s	51	52	59	55
unadjusted total engineering hours	1980s	1.2 mil.	3.5 mil.	3.4 mil.	2.5 mil.
	1990s	1.3 mil.	2.3 mil.	3.2 mil.	2.5 mil.
adjusted total lead time (mo.)	1980s	45	61	59	53
	1990s	55	52	56	55
adjusted total engineering hours	1980s	1.7 mil.	3.4 mil.	2.9 mil.	2.5 mil.
	1990s	2.1 mil.	2.3 mil.	2.8 mil.	2.5 mil.
% of supplier proprietary aprts	1980s	8	3	6	6
	1990s	6	12	12	10
% of black box parts	1980s	62	16	29	40
	1990s	55	30	24	35
% of detail-control parts	1980s	30	81	65	54
	1990s	39	58	64	55
prototype lead time (mo.)	1980s	7	12	11	9
	1990s	6	12	9	9
die lead time (mo.)	1980s	14	25	28	22
	1990s	15	20	23	20
% of heavy weight PM projects	1980s	17	0	0	7
	1990s	25	20	0	12
% of mid to heavy PM projects	1980s	83	17	36	52
	1990s	100	100	83	92
% of common parts	1980s	19	38	30	27
	1990s	28	25	32	29
product complexity index	1980s	95	92	83	90
	1990s	68	76	100	85

Source: Ellison, Clark, Fujimoto, and Hyun (1995)
Note: For the methods of adjustment for product complexity and definition of product complexity index, devised by Ellison, see appendix of the above paper. For other definitions, see also Clark and Fujimoto (1991).

Table 4: Alliance Relationships between Japanese, US, and European Automakers from 1985 to 1998.

	By Region (receiving firm)			Alliance Type				Total
1985	Japan	USA	Europe	Equity Relat.	JV	Tech./Prod.	Sales	
Japan	4	8	1	4	1	7	1	13
USA	5	0	0	4	1	0	0	5
Europe	1	3	14	1	8	8	1	18
Total	10	11	15	9	10	15	2	36
1990	Japan	USA	Europe	Equity Relat.	JV	Tech./Prod.	Sales	**Total**
Japan	8	19	15	5	11	15	11	42
USA	10	2	3	5	7	2	1	15
Europe	8	2	35	2	6	37	0	45
Total	26	23	53	12	24	54	12	102
1995	Japan	USA	Europe	Equity Relat.	JV	Tech./Prod.	Sales	**Total**
Japan	14	15	16	2	9	25	9	45
USA	9	2	5	4	8	3	1	16
Europe	8	4	39	1	15	35	0	51
Total	31	21	60	7	32	63	10	112
1998	Japan	USA	Europe	Equity Relat.	JV	Tech./Prod.	Sales	**Total**
Japan	15	14	9	2	9	24	3	38
USA	10	2	6	6	8	3	1	18
Europe	6	4	39	3	13	33	0	49
Total	31	20	54	11	30	60	4	105

Note: The figures represent the number of alliance relationships among the top 20 automobile manufactures in the years listed.
The figrues do not necessarily represent the total number of alliances. For example, in cases of the multiple existence of one alliance type (e.g. two joint ventures) between a set of firms, the relationship is counted as one alliance.
The row country name represents the country of the providing firm (providing, for example, capital, components, and technologies).
The column country name represents the country of the receiving firm.
If the alliance relationship is bi-directional, then it is counted as once each as a sending firm and a receiving firm for both firms.
If this treatment should be considered as double-counting, the adjusted number of alliance relationships, excluding the double-counting, in total is 29 (1985), 71 (1990), 72 (1995), and 73 (1998).
Alliance relationships in regions outside of the United States, Europe, and Japan are not included.
Equity relat. = Capital participation, M&A; JV = Joint venture; Tech./Prod. = Technology supply, OEM supply, Parts supply, Joint production, Joint development; Sales = Sales/dealer cooperation
Included automobile manufactures: Toyota, Nissan, Honda, Mitsubishi, Mazda, Suzuki, Fuji Heavy (Subaru), Daihatsu, GM, Ford, (former) Chrylser, Rover, VW, (former) Mercedes-Benz, BMW, PSA, Renault, Fiat, Volvo, Saab

Source: Complied from yearly editions of the Nikkan Jidousha Shinbun "Jidousha Sangyo Handobukku" [Handbook of the Auto Industry] (in Japanese).