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Toyota Motor Corporation: Launching Prius

"Should we accelerate the launch schedule for Prius?" Hiroshi Okuda, president of Toyota Motor Corporation (TMC), pondered, when the bullet train left Tokyo Station and began to gain speed. The train was headed for Nagoya. In Toyota City (about 30km away from Nagoya), a meeting to discuss the plan for Toyota's first hybrid vehicle was scheduled for the following day. His engineers had proposed a plan to introduce the car at the end of 1998, with expected production of 1000 units per month for at least the first three annual cycles. The engineers viewed this target as aggressive since they still had significant technical problems with the hybrid powertrain and saw mass production as an even greater challenge. The first prototype developed in November had not even moved for 40 days.

Okuda, appointed to presidency a few months earlier in August 1995, believed the company had to change. He felt that this car had the potential for radically altering the image of TMC, but was concerned that another automaker might bring a hybrid vehicle to the mass market first. Should he push for a more aggressive timing of launch or, given the technical problems, perhaps delay the program to ensure a smoother launch? And how might this program allow him to make progress on his more general vision for TMC?

The Automobile Industry

In 1994 global motor vehicle production was 49 million units. The United States was the largest national market with about 9 million new registrations, followed by Japan, with over 4 million registrations. The total number of motor vehicles in use worldwide was 644 million units.[1] Thirty-five million passenger cars were produced, up 4.1% from the previous year, but down 2.6% compared to 1990. Automobile sales were cyclic, falling during economic downturns and rising during periods of strong economic performance.

Prior to 1970, competition in the industry was largely regional with manufacturers developing designs suited for their region. For example, U.S. consumers who faced lower gasoline prices and drove on wider streets purchased larger, more powerful vehicles than their European and Japanese counterparts (see **Exhibit 1**).

The 1970s were a difficult but defining period for the industry, especially in the United States. Due to gasoline price hikes following the Arab oil embargo in 1973 and the Iranian revolution in 1979, U.S. demand for smaller, more fuel-efficient cars grew, and automakers rushed to offer such models.

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Japanese producers expanded their shares in the United States, while the Big Three suffered from a lack of expertise in small cars.

A host of new technologies was introduced in passenger cars in the 1980s. These included new engine technologies, sophisticated electronic controls, and more extensive safety features. There was also increased use of new materials such as plastics and ceramics. Robotics and computers were introduced to assist design and manufacturing processes. Those changes increased the capital expenditure requirement for auto manufacturers.

Over time, automakers became increasingly good at identifying new demand segments (e.g. minivan, SUV, near luxury cars) and responding to shifts in consumer preferences. For example, from 1980 to the mid-1990s the U.S. market share of vans, SUVs, and pickup trucks rose from less than 20% to about 40%. Model and vehicle concept types proliferated leading to increased segmentation and a decline in the number of annual units sold for each model: by the late 1980s, the leading model might sell 400,000 units versus 1.5 million in the late 1950s.[2] Although the number of models greatly increased, scale and manufacturing considerations led automakers to increase the use of common components (e.g. engines) across models and reduce the number of platforms (shared set of components or vehicle architecture) across their product offerings. The typical product cycle of an automobile model in 1995 was four to six years, with a few styling changes taking place during the cycle. The product cycle of a powertrain ranged from six to ten years.

To many people, automobiles offered aspirational value in addition to a basic mode of transportation. Consumers made purchasing decisions based on the styling, color, and concept of the cars in addition to functions and pricing. As the product technology advanced and the functionality of cars became more uniform, the importance of this aspirational value increased.

Automakers were quick to imitate each other's product ideas and most innovations did not provide long-term advantage. However, design and production quality as well as design and productive efficiency varied widely across automakers. Traditionally, the high-end European manufacturers produced the best designs while the top Japanese firms had advantages in production quality as well as design and productive efficiency.[3] The productive gap among automakers remained startling. The Harbour Report reported that the labor hours per vehicle between Ford's U.S. assembly plants and Nissan's U.S. assembly plants was 38 and 27, respectively. The hours per vehicle for GM and Chrysler were worse at 46 and 43, respectively, while the hours for Toyota and Honda were 29–31 hours.[4] Further, there was also a substantial gap in design efficiency: even adjusting for the complexity of a project, Clark and Fujimoto found that the top Japanese firms took less time (45 months versus 60 months in the mid-1980s) and used fewer resources in product development than their counterparts in Europe and the United States.[5]

Competition

As a result of intensifying competition and industry consolidation, the top twelve auto manufacturers accounted for nearly 80% of the global market by 1994 (see **Exhibits 2**, **3,** and **4)**.

The U.S. "Big Three"

The U.S. Big Three consisted of General Motors (GM), Ford, and Chrysler, which had 1994 U.S. passenger car market shares of 34.0%, 21.6%, and 9.0%, respectively. Each Big 3 firm recovered from enormous losses in the early 1990s to make record profits in 1994.

General Motors (GM) was the world's largest producer, selling 8.3 million vehicles globally in 1994. GM's market share declined from 43.4% in 1975 to 40.3% in 1985 and 32.3% by 1994. Its strategy was to offer a full array of models, but it had concentrated on mid and full sized cars, emphasizing performance and appearance. In the SUV segment, GM lagged behind Ford and Chrysler. In 1990, GM established a new company within itself to build small cars named "Saturn," which won awards for quality, customer service, and innovative management practices. In the early 1990s, GM reduced its workforce, rationalized operations, and divested non-strategic assets. GM's motto became "Run lean, get common, and compete globally."[6] While GM focused on brands such as Buick, Cadillac, Chevrolet, and Saturn in the United States, in Europe it emphasized brands such as Opel, Vauxhall, and Saab. In Western Europe, GM was the second largest automaker and its Eisenach factory, built in 1990 in East Germany, boasted the highest productivity in Germany. But the company was less efficient in product development, and its time to market was about 48 months.

Ford was second to GM in vehicles sales and revenues, but its net profits exceeded GM's for eight of the past nine years. In 1994 the Ford Taurus remained the top selling vehicle for the third straight year. Explorer defined the U.S. SUV market. Ford had also been consistently strong in trucks and accounted for 34% of all trucks produced in North America.[7] In 1979 Ford acquired 25% of Mazda, the fifth largest automaker in Japan;[8] recent transactions included purchases of Aston Martin and Hertz Corporation in 1987 and Jaguar Cars in 1989. Compared to GM, Ford had a more centralized approach in management and marketing, and the Ford brand was marketed globally. Ford experienced difficulty in unifying U.S. and European operations and demonstrated inconsistency in management. In April 1994, faced with the need to improve quality, reduce cycle times, and lower costs, Ford announced an ambitious restructuring plan named "Ford 2000," which called for dramatic cost reductions by reengineering and globalizing corporate organizations and processes.

Chrysler was saved in 1980 from bankruptcy by a government bailout that took the form of a $1.5 billion loan guarantee. Over the years, Chrysler had lost significant domestic market share and between 1986 and 1991 fell from being the #6 automaker to #10 worldwide. Chrysler enjoyed strong profits from trucks (about 60% of its vehicle sales), but suffered from quality image problems. The company was strong in product development and its time to market was in the mid 30 months on average, shorter than its U.S. rivals. [9] Unlike GM and Ford, Chrysler depended heavily upon the North American market.

Volkswagen (VW) was the largest automobile manufacturer in Europe. Unlike other European manufacturers that concentrated on certain segments, VW boasted an even distribution of sales among different classes with its four car brands. Smaller cars and the mass segment for compacts (Golf) and lower-end medium-sized cars (Vento) each comprised about one third of sales, respectively. The rest of sales were generated in the more profitable midsize and executive segments (Audi and Passat) and minivans. Sales outside of Germany accounted for about 60% of revenue.[10]

Bayerische Motren Werke (BMW) Group was the fifth largest automaker in Europe. The company derived about 30% of its sales from non-European markets. BMW had successfully shifted the emphasis of its products downmarket without affecting its status as a premier producer of sporty executive cars.[11] BMW, its flagship brand comprising 55% of its sales, had built a very strong image across all markets. The other brands included Rover (34% of the company's sales), Land Rover (9%), Mini (2%), and MG.

Nissan, founded in 1933, was the second largest automaker in Japan with 21.2% share (excluding mini[12]) in 1994. In 1994, it incurred a net loss of ¥87 billion over sales of ¥5.8 trillion due to the stronger Yen and excess capacity built in late 1980s. Historically Nissan had been known for its technological excellence, and boasted a 33% Japanese market share during the 1970s.[13] But its market share gradually declined because the company was weak in marketing and spread its resources too thin: its debt to capital ratio climbed, and it registered losses in 1993 and 1994. Nissan shifted its manufacturing facilities overseas earlier than its Japanese rivals, and its production capacity was more geographically balanced than that of Toyota, which relied heavily on its domestic facilities, and Honda, which relied on in the U.S. market more heavily than other Japanese companies.

Honda was Japan's third largest automaker and the world's largest manufacturer of motorcycles. In 1972 Honda developed CVCC (compound vortex controlled combustion) engines and became the world's first company to meet the strict environmental regulations under the Muskie Law enacted in 1970.[14] From 1974 to 1978, its Civic sedan recorded the highest fuel efficiency in the test conducted by the Environmental Protection Agency in the U.S.[15] Honda cars such as the Accord and Civic became popular among the younger generation both in the U.S. and Japan. In October 1994, Honda introduced *Odyssey*, a successful minivan that created its own market. *Odyssey* was followed by another successful minivan named CR-V launched in fall 1995. The company was also known for its investment and production efficiency, which was in part due to its efforts at minimizing plant changes and retooling costs.

Challenges to the Automobile Industry

Market Challenges

About 80% of the automobiles in the world were driven in OECD countries, which accounted for less than 20% of the world population. Manufacturers expected that the bulk of future growth in automobile demand would come from outside the OECD. Selling to less wealthy consumers in these emerging economies could require different product designs, production configurations, and marketing strategies. Moreover, incremental demand arising from those new markets presented significant environmental challenges.

Some observers predicted that automobile production might increase as much as 50% by 2010. As gasoline accounted for about 30% of the global demand for oil, this growth could put substantial upward pressure on oil prices.[16] Oil supply also could fluctuate dramatically depending upon the political conditions in the Middle East (where about 70% of the world's oil reserves were concentrated[17]) and the ability of OPEC to control its members' output.

Governmental and Regulatory Challenges

Automobiles were subject to many governmental regulations because of public concern about safety, traffic congestion, air pollution, and fuel scarcity. American legislators began regulating the safety of automobiles seriously after the 1965 publication of crusader Ralph Nader's *Unsafe at Any Speed.*

Governments also encouraged manufacturers to increase the fuel efficiency of their vehicles, in part to control emissions and in part to slow the depletion of oil supplies and mitigate concerns about reliance on oil imports. In 1975, in response to the first oil crisis, the U.S. Congress imposed Corporate Average Fuel Economy (CAFE) standards on all auto manufacturers in the United States. The law required the average miles per gallon (mpg) of each manufacturer's car output in a year to be 18 mpg by 1978 and to improve to 27.5 mpg by 1985. At the time of enactment, domestic fleets averaged around 12–13 mpg. Importantly, however, sport utility vehicles (SUVs) were classified for regulatory purposes as light trucks and thus were not included in CAFE calculations.[18]

On the environmental front, public concern had historically focused on tailpipe emissions of hazardous pollutants. In Japan, for example, automobiles were estimated to account for 40%–50% of the emissions of nitrous oxides (which reacted with hydrocarbons, also emitted by cars, to form smog). In the United States, highway vehicles accounted for over 60% of carbon monoxide emissions.

Governments responded with vehicle emissions regulations which were met by a number of means including engine retuning, better engine design, and technologies such as catalytic converters. In the early 1990s, this historic concern was augmented by worries about global climate change, caused by the carbon dioxide that resulted from the combustion of fuels. (The transportation sector accounted for almost one third of carbon dioxide emissions in the United States). International meetings of world leaders to discuss climate change were scheduled for Geneva in 1996 and Kyoto in 1997.

The State of California had consistently initiated aggressive environmental regulations in advance of those of the U.S. federal government. These technology-forcing regulations often influenced other states and federal law as well as regulations in other countries.[19] In 1990, the California Air Resources Board (CARB) adopted a Zero Emission Vehicle (ZEV) program. Among other things, the 1990 program mandated that 2% of all cars sold in California emit zero tailpipe emissions and zero evaporative emissions by 1998, and that this fraction must increase to 10% by 2003. By 1995, however, CARB was under pressure to revisit these requirements because of the slow progress on the electric and fuel cell technologies for vehicles that would enable manufacturers to comply.[20]

Global Leadership Challenges

By the early 1980s, the major automobile producing countries exported nearly 40% of their production, compared to 17% in 1965. Entry into foreign markets was expensive requiring, among other things, the establishment of a dealer network and heavy advertising expenditures (e.g., advertising in the United States could exceed a few hundred dollars on a per car sold basis [21]). Because of the importance of domestic automobile industries, many nations adopted trade barriers to slow automobile imports, especially from efficient Japanese producers which, for example, had obtained a 34.5% market share in the U.S. small car market in 1982. To partially circumvent such barriers and the effects of a rising Yen, Japanese manufacturers began building "transplant" assembly plants in the United States and Europe. Such plants could involve investments of greater than $2 billion for plants with capacities of up to 400,000 units per year. [22]

Increased globalization of the industry intensified competition, and many companies pursued cross-border acquisitions and alliances to achieve scale and scope economies. By the 1990s, the industry had become truly global, with a dozen leading players vying for shares in all major markets.

Automotive Powertrains

A number of different powertrain technologies held promise for lowering emissions and increasing fuel economy.

Improved Gasoline Engines. The conventional internal combustion gasoline engine takes in a mixture of gas and air, compresses it, and ignites the mixture with a spark. *Lean-Burn Engines* improve the fuel efficiency 2%–15% over conventional gasoline engines by increasing the air-fuel ratio (e.g. from 14.5:1 to as high as 22:1) under light load conditions. Cumulative production of lean-burn engines exceeded 300,000 by mid 1990s. Most of these engines were sold in Europe and Japan, though in the Japanese market consumers showed little interest in these engines (Toyota, Honda, and Mitsubishi were selling only 1500 vehicles equipped with lean-burn engines per month in 1994[23]). *Direct Injection,* which allowed the engine to run on an ultra-lean ratio was believed to have the potential to achieve over a 30% improvement in energy efficiency.[24] In May 1995, Mitsubishi Motor announced that it had developed this technology, which shocked many companies (including Toyota) that had been racing to be the first.[25]

Diesel Engines. Diesel engines compress air at a much higher ratio than gasoline engines, which allows the heat of the compressed air to spontaneously ignite the diesel fuel. Diesel engines produce less CO and CO_2 but many more particulates than similar-power gasoline engines. Excellent fuel economy—about a 25% improvement over gasoline engines—led diesel engines to gain popularity in Europe in 1990s, where diesels accounted for 23% of passenger car registrations in 1994.[26] But diesels had little market share in the United States and Japan because of their poorer performance and higher particulate emissions relative to conventional engines. *Common Rail diesel* technology showed promise for significantly reducing exhaust emissions and lowering engine noise while improving fuel economy another 20%. Denso, the leading auto parts supplier affiliated with Toyota, developed the world's first common rail diesel engine in October 1995, which was installed in Hino trucks.[27]

Electric Vehicles. Electric vehicles run on batteries and have no tailpipe emissions. By the mid 1990s, 2,000–5,000 electric vehicles were in use in each country including United States, Japan, France, and Germany.[28] But lack of power, long charge times, and the high cost of batteries limited sales, and many companies, being skeptical about its future potential, discontinued development. It was believed that electric vehicles could cost five times as much as gasoline vehicles and had less potential for benefiting from scale economies.[29]

Fuel Cell Vehicles. Fuel cells are electrochemical conversion devices that convert hydrogen and oxygen into water, producing electricity and heat. They work like batteries and are considered to be the environmentally cleanest powertrain. In 1994, DaimlerChrysler unveiled the world's first prototype vehicle based on this technology, NECAR 1. But infrastructure issues (the need to build stations to supply hydrogen) and the high cost of batteries presented significant hurdles to commercial production. The timing associated with the development and diffusion of mass production fuel cell vehicles was also very uncertain. For example, the Japanese government estimated a diffusion rate for this technology in motor vehicles to be about 1.7%–3.0% in 2010. [30]

Toyota Motor Corporation

TMC traced its roots to Sakichi Toyoda who was born in 1867 in Mikawa Region, Aichi Prefecture, where the modern Japanese cotton industry had developed. From 1890 through 1924, he developed a number of looms and founded Toyoda Automatic Loom Works. The Type G automatic iron loom with nonstop shuttle-change motion was especially successful.

"Open the paper door. The world is wide open," Sakichi advised his son, Kiichiro Toyoda.[31] In 1930 Kiichiro began developing a small engine and in 1937, this business was spun off, forming the foundation of TMC. The company developed several methods such as just-in-time production to overcome the inefficiency associated with its small production volume. The tight monetary policy and the depression following the Second World War drove Toyota near bankruptcy in 1950; over 2,000 employees were let go and Kiichiro Toyoda, who resisted laying off employees, resigned from the presidency. This experience contributed to Toyota's conservative corporate culture.

Toyota grew rapidly during the 1960s, riding Japan's strong economic growth. Its annual domestic unit sales reached one million in 1962. Corolla, its most popular model, was launched in 1966. Until the mid 1970s, TMC's market share was not much different from Nissan's, but TMC consolidated its leading position by 1980. Toyota became known for its prowess in marketing and sales as well as its production efficiency. Meanwhile, its exports reached a cumulative total of 10 million vehicles in 1979. By 1994, Toyota boasted over a 7% market share in North America, higher than any other foreign automaker,[32] and had the lowest number of problems per 100 vehicles according to J.D. Power.[33]

A critical part of Toyota's success was the Toyota Production System (TPS). The TPS system emphasized the importance of making problems visible so that everybody should understand the issues. *Andon* was a good example; when a line worker found a problem, the worker pulled the *andon* cord to stop the entire line. All the workers got together to identify the underlying cause and solve the problem.

During 1980s, U.S. manufacturers, alarmed by rising shares of Japanese automakers in their home turf, scrutinized the Toyota Production System. The U.S. Big Three, following their own internal efforts to benchmark best practices, independently created major initiatives to develop Toyota-like systems, but failed to replicate Toyota's performance.[34] The secret of Toyota's strength lay in commitment to learning. Its management firmly believed that people were the most significant corporate asset and that investments in their knowledge and skills were necessary to build competitiveness.[35] Each employee was trained to solve problems scientifically and to commit to *kaizen* or incessant improvement. Inculcation of the scientific method at all levels of the workforce allowed the company to drive down the cost continuously.

TMC also had a long-standing concern with environmental issues. In 1992 the company adopted "The Earth Charter" to underscore its commitment to environmental protection and its "Guiding Principles," also included a commitment "to provide clean and safe products."

Challenges and Responses

Japanese automakers lost steam in 1990s due to a stronger Yen and weak domestic demand. The Japanese currency, which traded in ¥140–¥160/$ range in 1990, quickly appreciated to around ¥100/$ by 1994, greatly increasing the relative competitiveness of the U.S. manufacturers. Meanwhile, some observers argued that U.S. manufacturers had narrowed the quality gap and had become very competitive.[36]

Japanese domestic sales (excluding mini vehicles) peaked at 6.0 million units in 1990 and dropped about 18% to 4.9 million units by 1993. Toyota's domestic sales declined faster than the overall Japanese market; its share dropped from the peak of 42.7% in 1988 to below 40%, and its share for the month of December 1994 was 36.5% (excluding mini). Net profits shrank from ¥441 billion in 1990 to ¥126 billion in 1994, while revenue declined 17% (see **Exhibit 5**).

Toyota withstood the adverse environment by cutting costs and these cost reduction efforts went beyond the factory floor. In September 1992, Toyota reorganized its 12,000 engineer R&D division to create four centers and consolidate administrative functions. This reorganization reduced coordination time, thereby reducing product development time.

During this time, Toyota was criticized for its proliferation of look-alike cars. Its clientele tended to be older, and its products were less appealing to the younger generation. Toyota's products were perceived to be following rather than setting the trend. Corolla was Japan's bestselling car, but customers chose the car because of its value. In contrast, Honda cars were popular among younger generation, and their customers kept buying Honda cars as they grew older. In October 1994, Honda introduced a multi-purpose minivan named *Odyssey* into the Japanese recreational vehicle market, a market in which Toyota had a large market share. *Odyssey* won the car of the year award and sold over 10,000 units per month, far exceeding its initial target of 3,000 units. This "creative mover," combined a driving performance equivalent to that of a passenger car with a spacious interior and a large storage space.

Non-innovative product offerings were not the only cause of declining market share. The dealers had become distrustful of TMC management as the company had cut dealers' incentives to reduce costs.[37] Toyota also found itself more vulnerable to foreign exchange fluctuations and protectionist sentiment because it had not aggressively shifted production overseas as had Nissan and Honda (it had only two plants in the United States). Finally, the serious illness of Tatsuro Toyoda, TMC's president, left a leadership gap.

Okuda's Accession

On August 10, 1995, Toyota announced the appointment of Hiroshi Okuda, deputy president, as president. Okuda's appointment caught many people by surprise. As the first president coming outside the Toyoda family in 28 years, some thought the appointment was only temporary.

Okuda, born in 1932, joined Toyota Motor Sales in 1955 after studying business and playing judo (he holds a black belt) at Tokyo's Hitotsubashi University. The press described Okuda as shrewd, outspoken, sociable, quick, and impatient. Okuda came up through the ranks in the accounting division, oversaw the Philippine operations from 1972 through 1979, and was appointed director in 1982.

As a director, Okuda was instrumental in launching Toyota's successful luxury brand, Lexus.

> I played an important role as leader by making a proposal, building consensus among management, and completing the project. Among top management of Toyota, there were some who were against this project since Toyota already had Crown as a luxury brand. It took a lot of time and effort to convince them, and I felt a lot of pressure, as I was only a director, not a senior executive, at the time.

Going by Toyota's principle, *genchi genbutsu* (go and see by yourself), Okuda worked tirelessly to bring the Lexus project to a successful completion, including taking numerous test rides at midnight during the dead of winter. It was important for him to exercise leadership by persuading others of his commitment and willingness to take "the final responsibility for the project." He said, "I believe Toyota's strength lies in the close relationship between management and employees."

As President, Okuda identified three critical challenges: weak product planning, decline in the domestic market share, and delay in shifting production overseas. He wanted to change Toyota into a young, aggressive company. Many people said that the company was at a crossroads and a complete makeover was required.[38] Some worried, however, that it would be difficult for someone outside the Toyoda family to implement a big change.

In anticipation of the introduction of four new models, Okuda declared in late August that Toyota should regain 40% market share and sell 700,000 units in three months. He also made a commitment to increase spending on dealers' incentives and advertising. But the business environment remained tough. The production plan for 1995 was later cut[39] and Toyota's market share did not recover to the 40% level.

The Car for the 21st Century

During Japan's "bubble" economy in the 1980s, automobile varieties and excessive features proliferated. Eiji Toyoda, then chairman, questioned, "Should we continue building cars as we have been doing? Can we really survive in the 21st century with the type of R&D as we are doing now?"[40] Acting on such concerns Yoshiro Kimbara, executive vice president in charge of R&D, founded a project committee in September 1993 to conceive the car for the 21st century.

Takeshi Uchiyamada was appointed as leader of this G21 team. The assignment was a big surprise for him. "Why me?" At Toyota, product leaders usually were drawn from personnel that had extensive experience as part of a product development team. Uchiyamada lacked that experience, but this project was different because it was to develop a car for the 21st century and to develop new car-development methods. He recalls being told by Kimbara "For that innovation, you are the best person because you are not the expert of the current method!"

Uchiyamada explained how the team went about developing the package design:

> Our team was authorized to develop any components we needed from scratch, which was unprecedented at Toyota. But it set a higher hurdle for us since we had to establish good reasons why we could not use existing components. We could not rely on conventions established on existing models. So we decided to eliminate all the assumptions. For example, we thought from scratch about the ideal sitting posture for a driver and passengers.

The organization of G21 was quite unusual for Toyota. Normal product development involved interactions that were moderated by strong reporting relationships to the functional departments from which team members were drawn. Here the ten engineers, mostly assistant managers from various Toyota engineering divisions, worked in a "big room with red carpets," which reduced the silo mentality and facilitated direct and less formal discussions among team members. "This level of interaction at the initial stage of product planning was new, and it later became a model for developing new cars," said Toshiharu Ishida, a member of the G21 team. Many Toyota people outside the G21 team thought G21's organization was somewhat chaotic.

After a lot of brainstorming, G21 team concluded that "resources" and "environment" should be the key concepts of the car for the next century.[41] "Our mission was to develop the car for the 21st century, a sedan which was friendly to the environment and friendly to people," explained G21-team-member Satoshi Ogiso.

By September, the team had developed a proposal based on a package design that offered Corona-level (mid-size) interior space in a Corolla-like (compact) exterior size. The proposal did not include a powertrain recommendation. At that time the hybrid was not proposed because the performance of the battery seemed hopelessly weak and costs were likely to be quite high.

Toward the end of 1994, the G21 team made a proposal based on a direct-injection engine with a fuel efficiency 50% higher than the conventional engines. Then Wada, who had replaced Kimbara as executive vice president in charge of R&D, demanded a 100% improvement in fuel economy (to about 28 km/liter or about 66 mpg using the Japanese 10–15 test cycle) versus an equivalent conventional car. (For comparison, the fuel efficiencies of an automatic transmission Corolla and Corona were 16.0 km/liter and 9.8 km/liter, respectively).[42] According to Wada, "People tend to become lazy if they have been working on the same project for a few years. Higher targets are better."

The only technology that might achieve 100% improvement in the near term was the hybrid technology. Advanced gasoline or diesel technology would not yield the needed improvement and fuel cell technology was still in its infancy (see **Exhibit 6**). But Uchiyamada was still skeptical about adopting hybrid technology. Wada gave him an ultimatum. "If you do not adopt hybrid technology, the G21 team has to be disbanded." Uchiyamada had no choice but to go forward with the uncertain technology.

> As leader, I kept three things in mind. First, I had to believe in my ability to succeed in the commercialization of hybrid cars. I cannot ask my team members to work on something I cannot believe in. Second, I tried to make decisions quickly since development time was limited and we had to solve many technological problems. Third, I was determined to take the responsibility if there were failures caused by the team members.

Toshihiro Oi, in the product planning division, pointed out this unique aspect of the development process, saying, "In the typical product development process, development of the engine comes first, followed by vehicle development. Then production engineers get involved to prepare for mass production. But in case of Prius, since we were developing an entirely new technology, it was necessary to develop new production technologies and do the three processes at the same time."

Hybrid Technology

A hybrid system combined different power sources that were teamed so each compensated for the other's shortcomings. A gasoline-electric hybrid system combined an internal combustion engine's high-speed power with the clean efficiency and low-speed torque of an electric motor. A hybrid car saved fuel by storing energy (recharging the battery) while the car was cruising or decelerating and then applying the stored energy to start or to supplement engine power during acceleration. (See **Exhibit 7**).

Toyota's Electric Vehicle Division began studying hybrid technology in 1993[43] TMC believed that it had internal capabilities to develop and manufacture all the key components for the hybrid system except for the batteries. In January 1995, a project team to develop a hybrid system was created, and Yuichi Fujii was appointed as leader. Fujii, an applied mathematician who joined Toyota in 1966, had been general manager of TMC's Electric Vehicle Division since 1993. Fujii's team began to work closely with Uchiyamada's G21 team toward a goal of developing a commercial hybrid vehicle. Takehisa Yaegashi, who had worked in engine engineering division since joining the company in 1969, explained the background:

> In early 1990s, major automakers began R&D on hybrid technology because of its potential to meet the CARB [California Air Resources Board] Zero Emission Vehicle regulations. When CARB said in 1992–3 that the hybrid will not be considered as an alternative for the ZEV, most companies lost interest and stopped development of hybrid cars. I proposed that Toyota should continue R&D on the hybrid in order to develop cars with dramatically better fuel efficiency.

Uchiyamada insisted on a thorough investigation of all available hybrid technologies. He instructed the team to study some 80 existing technologies and select the best ones based on fuel efficiency rather than technological difficulty or cost. Explaining his rationale, Uchiyamada said, "I thought we had to choose the most efficient technology in order to become a leader in hybrid cars. As an engineer, I did not want to choose an easy technology which would allow us to introduce hybrid cars to the market first, but might be replaced by superior technology later. Besides, I thought the cost would come down as Toyota was very good at reducing cost." Fujii recalled, "My boss said, 'Car makers always develop products after regulation have been enacted. We should reverse the relationship, anticipate what will come in the future, and develop products in order to create new markets.'" In June 1995, when G21 selected the best technology, the company made a formal decision to develop a commercial hybrid car to be introduced at the end of 1998, which would be a normal new-car introduction date for the Japanese market.

Automakers typically prepared backup plans when they undertook technologically difficult product development. Uchiyamada, however, insisted that no backup plans should be developed, which was considered crazy by many experienced chief engineers. He wanted to devote 100% of the engineering resources to development of hybrid cars.

In the automobile industry, development work to prepare for mass production was extremely important as it was critical for determining the overall profitability of new powertrain or vehicle programs. Uchiyamada noted that "meeting mass production reliability and quality targets accounted for 85%–90% of the development work for the Prius." Thus, even if Toyota engineers successfully built prototypes for a new hybrid vehicle, it did not necessarily mean that the company could produce 1,000 good quality units on the assembly line. Ford experienced such a problem in the late 1970s with its PROCO (Programmed Combustion Process) engine, which was considered the forerunner of the direct injection gasoline engine. The technology worked in prototypes, however, PROCO engine development stopped in the early 1980s because PROCO could not be mass produced.[44]

Technological Challenge

In hybrid vehicles, batteries and the control software were two key technologies. Batteries were especially critical for the performance of the vehicles. The batteries available in 1994 could produce 400–500 wpk (watts per kilogram), but 600–700 wpk was required for the hybrid vehicles. In spring 1994, Toyota began to work with Matsushita Electric. The two companies had jointly developed the nickel-metal hydride battery for RAV4-EV, an electric vehicle introduced in 1994. Only a few other companies were working on the nickel-metal hydride battery that TMC thought had the best near-term prospects.

Development of the batteries progressed very slowly through the first half of 1995. While the prototypes of the other hybrid engine components had been developed, the battery still posed major technical problems. One issue was that the battery was prone to overheating. Heat could reduce the battery's performance so much that the motor would sometimes fail to run. Overheating was also a safety problem. For a time, the engineers told the executives that they could not drive the prototype since it might catch fire during the drive.[45]

There were manufacturing and cost challenges as well. The battery for the hybrid vehicle consisted of 240 1.2-volt cylindrical batteries connected serially. Fujii said, "Since the battery required so many components, the production process became complex. As a result, it became very costly." Initially it was thought that the battery would account for about one third of the total cost of the hybrid system. The new, uncertain technology also had serious ramifications for warranty and service support issues.

Development of other components also involved significant technological difficulties. One problematic technology was the regenerative braking system in which the inertia of the moving wheels during deceleration and braking turned the motor, which acted as a generator. The recovered electricity was then stored in the battery. This braking system further improved fuel efficiency, but posed cost and reliability issues. Heated debates also took place concerning the development of insulated gate bipolar transistors (IGBTs), semiconductors that control the batteries, and whether the IGBT should be developed in-house or outsourced. Those engineers who believed that IGBTs were just as critical as engines or transmissions insisted they should be developed by electronics companies rather than Toyota's 10-year old semiconductor division.

Toyota had little information about competitors' hybrid efforts. Many automakers and some governmental groups were engaged in modest research efforts on hybrid systems. Some manufacturers had demonstrated small concept cars involving hybrid systems while a couple experimented with truck and bus prototypes using such systems. But it is two long steps from a concept to a prototype that showed technical feasibility and from such a prototype to a marketable production car that can be built at a reasonable cost.

Prius as a Business Proposition

It was decided that the hybrid car should be named Prius, a Latin word connoting an antecedent to a new epoch. Toyota executives faced difficulty estimating the demand for this new vehicle. As it was an entirely new category, they were not sure how consumers would perceive its value.

How much of a price premium over conventional cars would consumers be willing to pay for a hybrid car? Part of the premium might be justified by the savings on gasoline due to better fuel economy. The Prius offered an expected 100% increase in fuel economy over the 14 km/liter of a similarly-sized conventionally-powered car. Would individual consumers also value the Prius's contribution to reduced pollution? One survey showed that consumers were willing to pay at most 20% more for hybrid cars,[46] but such surveys were often unreliable and many outsiders remained skeptical. Hideaki Miyahara, in charge of product marketing, said in response, "I object to the idea that environment cannot be sold. The same was said of safety."

Acceptance in the marketplace would also depend on the reliability of the new vehicle and the perceived risk associated with a new technology. Even though engineers repeatedly tested the performance of the new vehicle under various stress conditions, it was impossible to initially reach the same level of reliability as gasoline engine vehicles. And if there was a technical problem, the issue would not be limited to the particular model; it could seriously damage the reputation of the Toyota brand.

Both development and incremental variable costs for the Prius program were expected to be large. The development cost was substantial since the technology was new and most of the components had been developed from scratch. Within the industry, it was generally believed that a new car and powertrain development program would cost between $750 million and $3 billion together depending on the novelty of each program and the development efficiency of the company.[47]

Additional development would need to be done to prepare the Prius for the North American market. Besides creating a left-hand-drive body, it was believed that better acceleration was needed as well as more reliability under the more demanding North American temperature conditions.

Even if Toyota decided to swallow the huge development cost, could it manufacture the vehicles at a profit? Shigeyuki Hori, said, "The engineers were focused on developing the new technology and could not devote resources to cost reduction." Moreover, the cost of key components (such as batteries) might not come down significantly as the production units were limited. Toyota managers estimated that the Prius would entail $3000 to $4000 more per unit in additional variable costs compared to a similarly sized gasoline-powered vehicle.[48] Thus, at least initially, Toyota might incur a loss on every unit it produced and sold. But the initial variable cost would fall with increases in scale and learning. Especially with new technologies, field experience was critical to lowering cost and increasing reliability. With respect to batteries, for example, Fujii estimated that "learning could be up to ten times faster with a volume of 300,000 batteries versus 20,000.

Strategic Importance of Prius

> "Consumers are smart. They recognize the threat that pollution and global warming present to them and their children."[49]
>
> — Hiroshi Okuda, President, Toyota Motor Corporation

While the introduction of Prius involved a lot of risks and costs, it promised long-term strategic benefits. Okuda felt that through introduction of Prius, the company could make a clear statement on its commitment to environmental protection and generate excitement about the company's products and innovative capabilities that had been missing for many years. These benefits would be maximized if Toyota was first to the market.

About 100 days had passed since he took over as president, and Okuda was fully aware that the decision on Prius could be a turning point at Toyota. Okuda had already become involved directly in the management of the program. According to him, "I listened to the progress report from each person and gave directions. It was probably the first time that the president became responsible for a single car. I gave directions directly to the general managers who worked for Wada, the most senior engineering executive."

He recalled his engineers' recommendation to launch the car in late 1998. This decision, made in June 1995, was already aggressive relative to the engineers' preferred 1999 launch. There was much more work left to improve the performance of batteries and to get ready for mass production. He wondered, however, if the launch timing could be accelerated even further to December 1997. Such a deadline implied the vehicle would have to be developed in 30 months. But it might ensure that Toyota would be the first to introduce hybrid cars and it would be a monumental achievement for the company.

In addition to the timing, he also wondered about pricing and the production volume. How should the company go about estimating the demand? Demand was of course linked to the pricing decision. If the car was too expensive, the market for hybrid cars might not take off at all. On the other hand, the company had to make money. In order to achieve the right balance, he also had to think about how the new vehicle should be positioned and marketed. And once the Prius was launched, then what?

Okuda looked out the window, thinking over the past 100 days since he became president. While he had already made a number of important decisions, he was well aware that the decisions on Prius were more tricky and would have far-reaching implications for the future of Toyota.

Exhibit 1 Average Miles Driven and Gasoline Prices by Country

Exhibit 1a. 1994 Average Distance Driven

	Japan	United States	Germany
Miles	6,648	12,809	8,047
Kilometers	10,696	20,609	12,948

Source: U.S. Department of Transportation, *Transportation Energy Data Book*, edition 17, 1997.

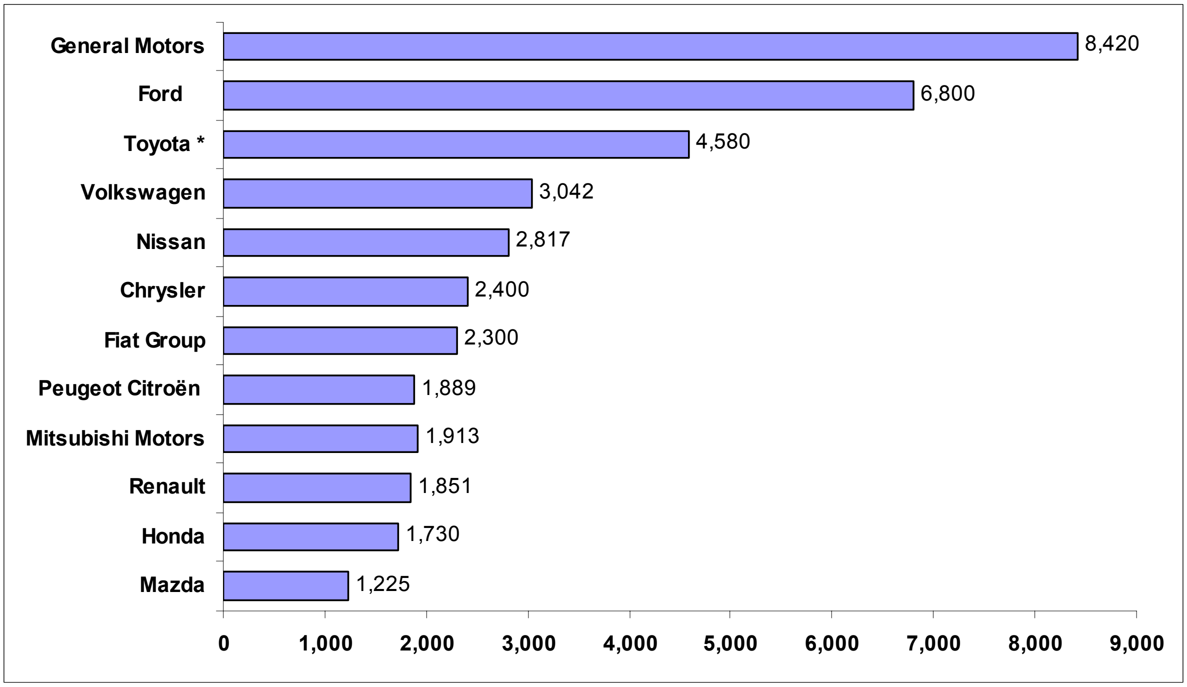
Exhibit 1b. Gasoline Prices per Country

	1978	1982	1986	1990	1995
$/Gallon					
US	1.32	1.79	1.11	1.04	1.13
Germany	3.51	2.94	2.24	2.72	3.35
Japan	4.01	3.52	3.33	3.05	3.91
cents/Liter					
US	34.87	47.29	29.32	27.47	29.85
Germany	92.72	77.67	59.17	71.85	88.50
Japan	105.93	92.99	87.97	80.57	103.29

Note: US Gallon is equivalent to approximately 3.79 liters.
Adjusted by US CPI to 1990 dollars

Source: US Department of Transportation, *Transportation Energy Data Book*, ed. 17.

Exhibit 2 The World's Largest Vehicle Sellers (1994 calendar year, units in thousands)



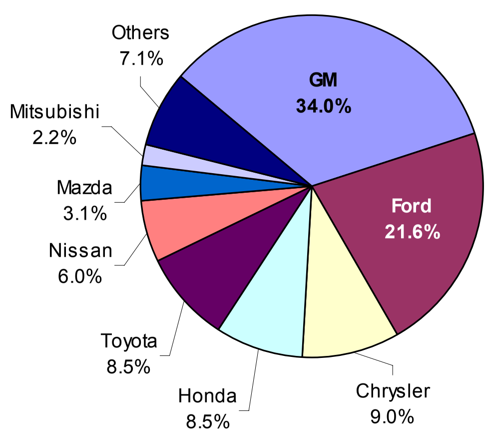
Source: Automotive News Data Center.

Includes automobiles, trucks, buses, and commercial vehicles.

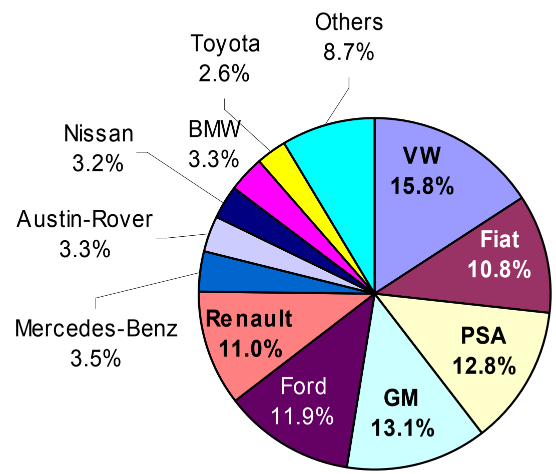
*Estimate.

Exhibit 3 1994 Passenger Car Market Shares in Selected Regions

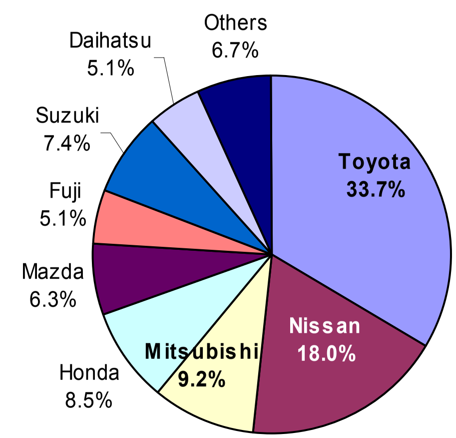
United States
Total Retail Sales: 9.0 million



WESTERN EUROPE
Total Retail Sales: 11.9 million



JAPAN
Total Retail Sales: 4.2 million



Source: *Ward's Automotive Yearbook 1995.*

Note: Japanese market shares include mini vehicles, a category of very small automobiles with engine sizes of 660 cc or less. Retail sales in W. Europe and Japan based on registrations.

Exhibit 4 Summary Financial Data for Selected Automobile Manufacturers

Company		Toyota	GM	Ford	Nissan	Honda	Volkswagen
Net sales, $ million	FY 1994	94,573	154,951	128,439	56,319	37,448	49,359
Net income, $ million	FY 1994	1,271	4,901	5,308	(844)	230	93
Total assets, $ million	at end of FY 1994	97,552	198,599	219,354	71,147	28,319	49,500
Book equity, $ million	at end of FY 1994	48,785	12,824	21,659	15,338	9,378	7,155
Current ratio	at end of FY 1994	1.66	1.02	1.05	1.01	1.05	2.03
Long-term debt/(Long-term debt + book equity)	at end of FY 1994	29%	33%	85%	60%	36%	27%
Median market to book equity ratio	during FY 1994	1.6	4.3	1.4	NA	1.5	NA
Net sales, $ million	FY 1994	87,806	154,951	128,439	56,319	37,448	49,359
	FY 1993	85,855	138,220	108,521	53,428	35,624	46,290
	FY 1992	77,770	132,242	100,132	48,255	33,022	54,682
	FY 1991	70,712	123,109	88,286	42,304	30,507	45,945
	FY 1990	64,951	124,705	97,650	35,729	24,385	42,101
Net income, $ million	FY 1994	1,180	4,901	5,308	(844)	230	93
	FY 1993	1,484	2,466	2,529	(483)	320	(1,173)
	FY 1992	1,820	(23,498)	(7,385)	762	449	94
	FY 1991	3,086	(4,453)	(2,258)	346	520	671
	FY 1990	3,118	(1,986)	860	734	517	672
Ending date of fiscal year		30-Jun-94	31-Dec-94	31-Dec-94	31-Mar-94	31-Mar-94	31-Dec-94

Source: Compiled by casewriters from companies' annual reports; additional exchange rate data from The Economic Report of the President.

Note: For VW, "long-term debt" is liabilities payable in more than 5 years.

Net sales and net income numbers for Toyota in the first two lines of the exhibit are as stated in Toyota's annual report, converted at period-end exchange rates which was slightly greater than 100 ¥/$ in mid-1994. In the lower part of the exhibit, net sales and net income numbers for Toyota, Nissan, Honda, and Volkswagen are computed at average exchange rates for the relevant period.

Exhibit 5 Toyota's Financial and Operating Information (billion yen)

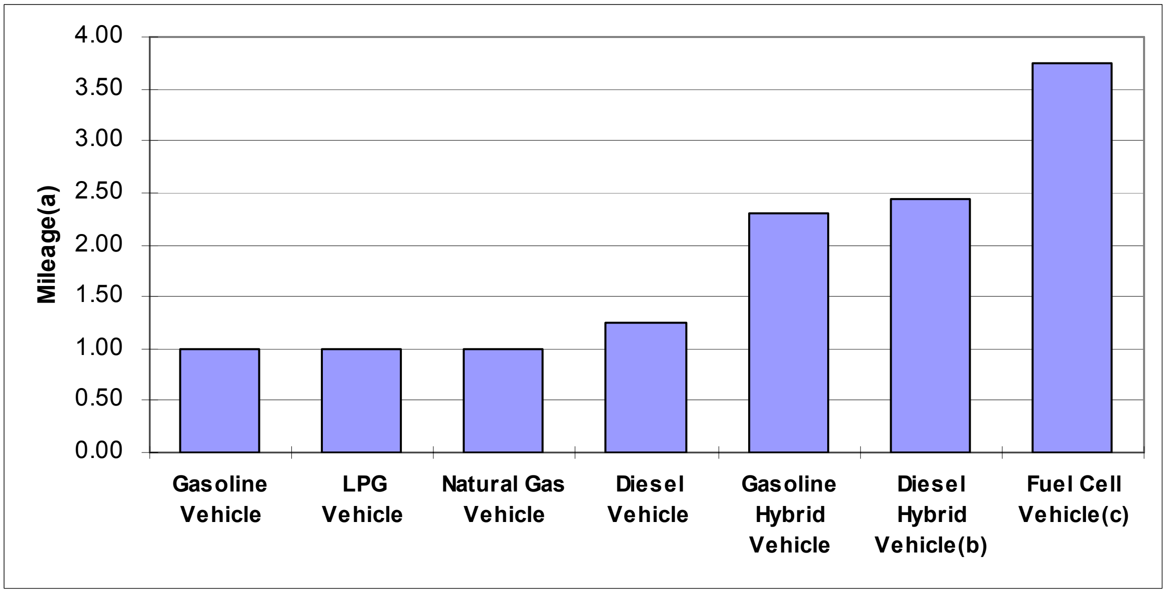
	For the Years Ended June 30,					For 9 Months Ended March 31, 1995 [a]	1995 (annualized)[a]
	1990	1991	1992	1993	1994		
Sales	9,193	9,855	10,163	10,211	9,363	8,121	10,828
Operating Profit	643	491	219	182	136	256	341
Net Profit	441	431	238	176	126	132	176
Operating Profit margin	7.0%	5.0%	2.2%	1.8%	1.5%	3.2%	3.2%
Net Profit margin	4.8%	4.4%	2.3%	1.7%	1.3%	1.6%	1.6%
Total Assets	8,431	8,988	9,583	9,414	9,568	10,396	NA
Shareholders Equity	4,236	4,578	4,719	4,763	4,830	5,021	NA
Capital Expenditure	526	804	768	556	330	283	377
Vehicles Sales ('000 units)							
Domestic	2,426	2,443	2,331	2,159	2,010	1,561	2,081
International	2,003	2,095	2,181	2,307	2,121	1,700	2,267

Source: Company documents.

[a]Annualized to a full-year basis by multiplying 4/3.

Exhibit 6 Fuel Efficiency

6a. Fuel Efficiency of Different Powertrains



Source: Mizuho Information & Research Institute, Well-to-Wheel Analysis of Greenhouse Gas Emissions of Automotive Fuels in the Japanese Context.

[a]Mileage per liter in which each fuel is converted into gasoline equivalence based on heating value. Represented in relative values to that of gasoline vehicle.

[b]Estimation from public documents.

[c]Future target.

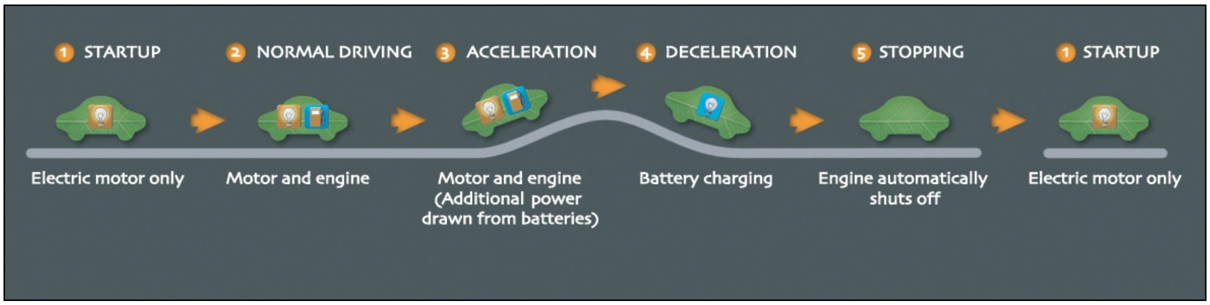
6b. Well-to-Wheel Efficiency

	Well-to-Tank[a] (fuel production efficiency) (%)	Tank-to-Wheel[b] (vehicle efficiency) (%)	Overall Efficiency (Well-to-Tank x Tank-to-Wheel) (%)
Recent gasoline car	**88**	**16**	**14**
Prius	**88**	**32**	**28**
Toyota FCHV[c]	**58**	**50**	**29**
FCHV Target[c]	**70**	**60**	**42**

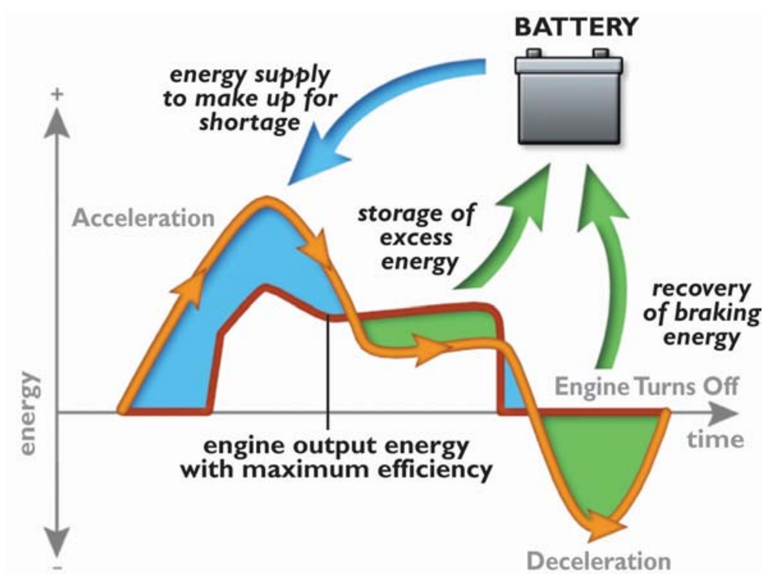
Sources: [a]Toyota study, Japanese energy conditions; [b]Toyota in-house testing, Japanese 10/15 mode; [c]Hydrogen from CNG.

Exhibit 7 How the Hybrid System Worked

7a. How the gasoline engine and electric motor complement each other



7b. How regenerative brakes work



Source: Company documents.

Notes

[1] Japan Automobile Manufacturers Association, Inc., June 13, 2005.

[2] Kim B. Clark and Takahiro Fujimoto, *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry*, HBS Press 1991, p. 36.

[3] Clark and Fujimoto (1991), p. 94.

[4] Harbour Report 1997. Note that these estimates did not adjust for complexity or type of vehicles and did not use different wage rates.

[5] Clark and Fujimoto (1991), p. 80.

[6] As reported in Harbour Report 1997.

[7] Ward's Communications, *1995 Ward's Automotive Year Book*, p. 90.

[8] *Japan Economic Journal*, August 1, 1979. In 1996, Ford increased its ownership in Mazda to 33.4% (*Japan Economic Journal*, April 12, 1996).

[9] Harbour Report, 1989–92.

[10] Research report, *Volkswagen*, Deutsche Morgan Grenfell, October 15, 1997, p 23.

[11] J. Longhurst, et al., *BMW*, UBS Research Limited, January 7, 1994.

[12] Mini referred to a category of very small automobiles in Japan of engine sizes of 660 cc or less.

[13] Michael Yoshino and Masako Egawa, *Nissan Motor Co., Ltd., 2002*, HBS case (9-303-042).

[14] Toyota was the first company to license this technology (*Asahi Shimbun*, November 30, 1972).

[15] Honda Motor Co., Ltd. (1999), *Things to Pass On: 50 Years of Challenge*, Honda Motor Co., Ltd., p. 111.

[16] Petroleum Association of Japan, July 29, 2005.

[17] It was believed that worldwide oil reserves, estimated at 1.02 trillion barrels at the end of 1994, would be depleted by the middle of the 21st century (Source: British Petroleum, *Statistical Review of World Energy 2005).*

[18] Keith Bradsher, *High and Mighty*, New York: Public Affairs, pp. 25-30.

[19] David Vogel, *Trading Up: Consumer and Environmental Regulation in a Global Economy*, Cambridge: Harvard University Press, 1995, p. 6.

[20] California Air Resources Board, *Staff Report; Low-Emission Vehicle and Zero-Emission Vehicle Program Review*, Sacramento, 1996.

[21] Ibid.

[22] James W. Brock, "Automobiles," in W. Adams and J. Brock, *The Structure of American Industry*, 10th edition, Prentice-Hall, 2001, p. 124.

[23] *Nikkei Business*, January 24, 1994.

[24] Ibid.

[25] *Nikkei Sangyo Shimbun*, May 19, 1995.

[26] This percentage varied in each country; the highest was France with 47.6% and the lowest was Denmark with 2.7%. Source: ACEA (European Automobile Manufacturing Association);

http://www.acea.be/ASB20/axidownloads20s.nsf/Category2ACEA/D3D0E3E056E803B2C125702F004A7D11/$File/DIESEL-PC-90-04.pdf, accessed on August 23.

[27] *Nikkei Sangyo Shimbun*, September 6, 1995; October 26, 1995

[28] Japan Automobile Research Institute, August 22, 2005.

[29] *Nikkei Business*, January 24, 1994.

[30] *Nikkei Sangyo Shimbun*, January 5, 1995.

[31] Masaaki Sato, *The House of Toyota*, Bungei Shunju, 2005, p. 505.

[32] Julia Beldini, *Toyota Motor*, Schroders Securities, December 9, 1994, p. 12.

[33] Christopher Redl and Keith Turelove, *Toyota Motor*, UBS Warburg, September 28, 2000, p. 16.

[34] Steven Spear and H. Kent Bowen, "Decoding the DNA of the Toyota Production System," *Harvard Business Review*, September-October 1999, p. 97.

[35] Ibid., p. 103.

[36] Interview of Maryann Keller by *Economist* (Japanese Weekly Magazine), October 26, 1993.

[37] *Japan Economic Journal*, August 13, 1995, p. 7.

[38] *Japan Economic Journal*, August 11, 1995, p. 3.

[39] *Nikkei Industrial Daily*, August 7, 1995, p.1.

[40] Itazaki, Hideshi, *The Prius That Shook the World: How Toyota Developed the World's First Mass-Production Hybrid Vehicle* (translated by Albert Yamada and Masako Ishikawa), p. 10.

[41] Yoshiro Ikari, *The Age of Hybrid Cars: How Toyota Developed the World's First Mass Production Car 'Prius,'* Kobunsha, 1999, p. 35.

[42] Toyota Motor Corporation, September 26, 2005.

[43] Hiroaki Iemura, *Prius as Dream: Door to the 21st Century Opened by Toyota*, Futaba Publishing, 1999, pp. 57–59.

[44] Kaiser, Walter, "The Growth of Ford's R&D in postwar Europe," http://147.210.86.202/ifrede/Ford/Pdf/Kaiser.pdf, accessed August 4, 2005.

[45] Itazaki, pp. 267–270.

[46] *Nikkei Sangyo Shimbun*, April 26, 1995.

[47] Development of Mondeo cost Ford $3 billion, establishing the highest record in the automobile industry (*Japan Economic Journal*, August 27, 1993). In comparison, Ford's Taurus required $2.5 billion (*Nikkei Business*, June 21, 1993), while Chrysler developed Neon with $1.3 billion (see p. 12 of this case).

[48] Richard J. Newman, "Invasion of the Green Machines," *US News and World Report*, May 9, 2005; Jathon Sapsford, "Toyota's Chief Bets on Hybrids, Squeezing Rivals," *The Wall Street Journal*, July 13, 2005, B2.

[49] "Our Precious Planet," *Time*, special edition, November 1997.