

Hydrocarbons to Hydrogen

Toyota's Long-term IT-based Smart Product Strategy

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Abstract

The recent world Expo in Nagoya signaled Toyota Motor Corporation's (TMC) emergence as the world's leading automobile manufacturer and provided a strategic insight concerning its plans to move vehicle transportation from dependence on hydrocarbons to hydrogen. In addition it showed that in pursuing this evolving strategy the long-term role of hybrid vehicles and the use of embedded IT in combination with organizational IT will continue into the hydrogen era.

There are important connections between the IT activities embedded in the automobile and TMC's well-researched production system, smart design, and globally based automated consumer ordering systems. This is because the efficiencies of these latter systems will enable TMC to continuously reduce the cost of the hybrid engine, fuel cells and embedded IT faster than its competitors, making them not only the industry's technology innovation leader, but also the continued cost leader too.

Their resulting control over not only the intellectual property related to hybrids on which they will receive expanding revenues as demand for hybrid vehicles grows, but also over the global supply chain in areas such as hybrid engines will cause continuing problems for competitors. The corporate culture that has resulted in TMC's on-going and well recognized leadership in quality, production efficiency and rapid product development combined with their deep financial resources means these embedded IT product initiatives and their global impact need to be taken increasingly seriously.

Introduction¹

Over the last 30 years certain countries have combined the Olympics and an Expo as a way to announce a change in their status on the world stage; examples include Japan's spectacular economic recovery, Spain's entry into the EU and China's emergence as a major global power.² So what was the purpose behind the recent World Expo in Nagoya? It indicated both TMC's emergence as the world's leading automobile manufacturer and provided a strategic insight concerning its plans to move vehicle transportation from dependence on hydrocarbons to hydrogen both as a way to address global environmental concerns, - the Expo's theme -, and as a way to alter the

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² Japan (Tokyo [1964] and Osaka [1970]), Spain (Barcelona [1992] and Seville [1992]) and most recently China (Beijing [2008] and Shanghai [2010])

competitive playing field in automotive transportation. This paper will focus on one aspect of that strategy by showing the role TMC intends hybrid vehicles and IT to play in these developments and why this strategy will continue into the hydrogen era.

Strategically Important Megatrends³

Importantly from TMC's perspective, as competitive pressures have mounted in Japan and global markets, global auto groupings such as GM, Ford, Daimler-Chrysler and Renault have absorbed many Japanese firms, though there has been some reversal such as GM's sale of Suzuki and Fuji-Heavy and Daimler-Chrysler's refusal to rescue Mitsubishi. These expanding groups have aggressively challenged the two leading Japanese producers, Toyota and Honda, in their export and domestic markets. So it continues to be critical to TMC's long-term strategy that it successfully maintains its position as the world's most efficient vehicle producer while managing its planned transition to a new competitive model.

For TMC there is no alternative business model since vehicle production and related businesses, such as replacement parts and finance, represent most of its revenues, operating earnings and invested capital. Furthermore the adverse consequences of GM's diversification acquisition binge are there for all to see. In this context TMC's organizational structure and product development choices enable one to understand how the company will use technological innovation, IT, and organizational evolution as strategic tools to maintain and extend its competitive advantage in producing, selling and delivering vehicles while always relying on its core philosophy.

³ This section is excerpted and updated from the Chapter on Toyota in author's book [Information Technology Strategies](#), Oxford Press, 2002

“Since its establishment, Toyota’s principle has been to strive constantly to build ‘better products at lesser costs.’ To this end, Toyota has developed its own unique production method. This system is based on the idea of ‘just in time’ (i.e. producing only the necessary amount of parts just at its needed time), the idea of Toyota Founder Kiichiro Toyoda. This system also seeks to thoroughly eliminate all sorts of waste in order to reduce prime costs. Toyota also places a maximum value on the human element, allowing an individual worker to employ his capabilities to the fullest through participation in the productive management, and improvement of his given job and its environment. With the motto ‘Good Thinking, Good Products,’ each individual worker is making his best effort to assure Toyota’s customers the highest quality product, with an understanding that it is in his work process that quality is built in.” (Quoted from Toyota's company booklet “Opening the Window”, p 13.)

Therefore for TMC, the objective is to make this already very productive approach even more productive in terms of output and product performance. By using these principles TMC firmly established itself in the late 1970s and early 1980s as the world’s most efficient and lowest cost producer of high quality automobiles. This was explained during the late 1980s in a series of studies organized by MIT’s Auto Industry Center, culminating in 1990 in Womack, Jones and Roos’ seminal work on lean production, The Machine That Changed The World. More recently Jeffrey Liker and David Meier have amplified the concepts, The Toyota Way. As a result other producers are well aware of TMC’s lean production principles and have spent years benchmarking them. But they have yet to catch up as TMC has continued to evolve the production system globally and even change it to make it even more flexible and productive. In addition, TMC has shifted the competitive model from one dependent primarily on

superior organization and manufacturing to one that also incorporates significant product innovation and the extensive use of electronics, telecommunications and IT.

In this way it has developed a strategy that is responding not only to industry changes but also trends in the economic and regulatory environment. California, the world's fifth largest auto market, has increasingly tightened the emission regulations on cars sold in the state. Several US and Japanese cities have publicly undertaken aggressive programs to improve energy conservation and achieve a better environment through reduced fuel emissions. The rapidly developing potential mega-markets of China and India face mounting environmental issues as well as rising oil costs, partially driven by an increasing global demand that is influenced by their own rapid economic expansions. Furthermore world oil production appears to be peaking, and, simultaneously, aging populations are increasingly health and environmentally conscious.

Thus producing environmentally friendly cars with lower emissions and improved fuel economy has become a key requirement for competitive success for the foreseeable future. Conversely heavy dependence on sales of large fuel guzzling SUVs has become a strategic liability as recent sales and loss figures for GM and Ford testify. Only TMC appears to have the vision on how to meet the challenges within the industry as well as how to get from a mobile transportation system dependent on oil to one that utilizes significant amounts of hydrogen.

The Role of Information Technology

IT plays an important role in meeting this competitive and strategic challenge on a sustainable basis. Yet TMC recognized much earlier than its major competitors that rapid developments in IT would have such a dramatic influence on what happened inside and

outside the automobile. In the early 1990s Mr. Okuda, chairman of TMC, foresaw these developments would change the industry's ground rules impacting TMC and the global automobile industry. This was based on his understanding of “ *three watersheds in the history of the automobile industry. Each time, a new business model changed the ground rules for the industry. Each time the new model seemed invincible. And each time, it gave way to changing circumstances and a new business model. ... Our old business model is breaking down for four main reasons. One, we need to decentralize our manufacturing and R&D activities ... Two, the product and process paradigms that Henry Ford established are themselves breaking down ... Three, information technology is transforming the inner workings of the automobile. It is also transforming the way we develop and make and sell our products. And four, the changing product paradigm and the growing role of information technology will open our industry to a vast array of competitors.*”⁴

This appreciation of the effects of Information Technology on the ways cars are produced and the working of the automobile itself has provided a driving vision that has pushed TMC's “smart” strategy based on smart cars, smart design and smart production that addresses both changes in the auto industry and its external context due to changes in environmental regulations, resource availability and demographics. In turn the results are changing the future of the automobile and the industry, and the impact on all TMC's competitors has been and will continue to be significant. As Mr. Okuda has correctly perceived, the nature of the global automobile industry is changing dramatically.

⁴ Excerpted from published speech Mr. Okuda gave at the Yale School of Management in 1998.

In the next two decades TMC's actions should have as much impact on the global automobile industry, as well as on transportation and logistics generally, as TMC's Production System had on trade and industry in the 1970s and 80s. This situation clearly demonstrates that even traditional products such as automobiles and old manufacturing processes such as assembly can be significantly transformed through the sophisticated integration of IT into products and business strategies.

Such routines have enabled TMC organizationally and competitively to build beneficial feedback cycles that increase productivity and improve products in areas as different as design, customer warranty service and product innovation in addition to reducing cycle times and improving the production and delivery of products and replacement parts to the customer.

TMC sees a continued merging of IT and the automobile as critical to its strategy not only external to the car but inside of it as well. Yet this strategic view of the growing importance of embedded software technology does not represent a radical strategic shift. Rather it continues in a new competitive and global context the constantly evolving product strategy the company has pursued for many years.

While not as well studied or analyzed as TMC's production system, part of TMC's successful competitive challenge to other automakers has been its ability to envision the automobile as a product that should be responsive to new technology. This was first apparent in the 1980s when it recognized customers saw cars as electronic devices in addition to transportation and image. This gave TMC a lead over the competition while allowing them to leverage Japan's dominance in high-quality, mass-produced consumer electronics.

A similar product transition took place in the 1990s when automobiles became a mobile telecommunications device, another area where Japan has led. Indeed, this advantage continues since Japan is currently the most advanced of the major industrial countries in introducing new 3-G mobile communications technology and mobile Internet access. In turn, TMC has combined these developments with a sophisticated navigation system that, in cooperation with the Japanese government, can now monitor and report traffic conditions on a real-time basis nationwide, something that the US is only now beginning, lagging behind Japan by more than 10 years.

Now TMC is integrating these products and their systems with multi-media devices, including related services and connections such as smart highways, mobile networks (MONET), and communication with kiosks in convenience stores such as 7-Eleven and Family Mart. This has led TMC into new businesses that include supporting systems for smart highways or multi-media kiosks (Rapp and Islam 2004). As TMC states, it “views IT, itself, as a genuine field of business and plans to establish IT as a full-fledged part of its overall business endeavors. “ In turn they are “determined to develop” their “existing networks into a new comprehensive operation that covers both content and platforms (access devices).” The aim is “to make cars more ‘informative’ and ‘intelligent’.” (TMC’s booklet “IT Interactive Toyota”, 2004)

This means equipping the car with information processing and communications platform devices as well as information functions that control the car. The end result is a car that provides users access to whatever information they need, wherever they need it, as well as a car that can be driven safely and comfortably.

The company does not see limits on where its IT initiatives might lead either inside or outside the car, and it will not limit itself to domains of business. Rather it is determined to expand its operations into all possible areas, covering content, platforms, networks and propulsion systems. Fully utilizing IT, TMC is determined to collect the latest information from a broad range of fields, combine and link such information, and open up new dimensions creating a “spiral value chain.” (IT Interactive Toyota) Such a strategic redefining of the automobile in its various dimensions by a major global strategic competitor will significantly affect the industry’s evolution over the next several years and raises many competitive issues that will be explored in this case study.

Hybrids and Hydrogen

The typical competitive response to TMC’s market success with hybrids especially among European manufacturers is to either claim that TMC is losing money on these cars or that the same fuel economy and environmental benefits can be achieved by making the traditional gas or diesel engine more efficient through technology improvements or innovations, such as high pressures charging. Strategically this is a dangerous misconception. This is because it does not recognize that the new hybrid engine systems can increase the efficiency of any propulsion system including high-pressure diesel or fuel cells. No matter what improvement a TMC competitor makes to a traditional diesel or gas engine TMC can copy that propulsion system and still make it more efficient by combining it into a hybrid. TMC is currently working on a diesel hybrid engine for the EU market. This result occurs because TMC’s hybrid system captures energy, such as what comes from braking that otherwise is lost. The second consideration is that as TMC extends hybrids to every model, market costs will drop with scale, scope

and learning, even as consumers seem willing to pay a small premium for these “green” cars.

When one combines these considerations with TMC’s proven ability to produce cars more efficiently than competitors, it becomes clear that TMC will not lose money but instead will expand its global market share. Conversely competitors that lag in this development will lose share while finding their own hybrids less competitive and more costly as they will be forced to rely on TMC’s global hybrid supply chain and pay TMC to license its technology. Dynamically this is a beneficial loop for TMC and an adverse one for rivals.

This result is critically important when one examines a possible transition to a hydrogen-based mobile transportation system. Using fuel cells and hydrogen that produces water as an emission is considered the nirvana of engine systems. Still many pundits claim that such a system could begin to emerge after 2020, though the actual start date is constantly extended due to the problem of developing an inexpensive but compact fuel cell that is not too heavy. The second issue is replacing the current ubiquitous gas station with a series of hydrogen terminals. TMC’s hybrid strategy to hydrogen addresses these issues in two ways.

First, because a hybrid system makes any propulsion system more efficient it reduces the fuel cell requirement to achieve a certain power output. This means that the cell required can be lighter. Since one of the problems with fuel cells is their weight and the fact the power required must account for this weight in addition to what is needed for the vehicle and its passengers, anything reducing fuel cell weight has a beneficial cycling effect by reducing the weight the fuel cell must propel and thereby the size of the fuel cell

required. TMC has already taken advantage of this fact to build a hybrid fuel cell combination bus (FCHV-Bus) that was successfully used at Expo (Official Guidebook, The 2005 World Exposition). The buses “run with motors powered by high-pressure hydrogen-supplied fuel cells and a nickel-metal secondary battery. Unlike conventional gasoline-fueled or diesel-powered vehicles, the FCHV-BUS emits water only, and no carbon dioxide or other substances. They are highly energy-efficient and emit little noise. These characteristics make hydrogen-powered fuel-cell buses suitable as mass transit vehicles for the 21st century.” (Official Guidebook, The 2005 World Exposition)

The buses are large enough to carry the large fuel-cell system, and, because the buses had a fixed route and terminal, it was efficient to have a hydrogen fuel terminal to service them. Such a system can easily be replicated in a city. Since buses are more expensive, the propulsion system represents a smaller part of the total cost and passengers can spread it over a large user base. Therefore it is TMC’s plan to sell this system to local cities in Japan and for public policy and environmental reasons we can expect the Japanese government to subsidize its use. The result will be a gradual expansion in the number of urban-based hydrogen terminals while TMC will move ahead on its learning curve in producing both more efficient fuel cells and hybrid systems. At some point it will become economic to sell similar systems to cities in the US or Europe that are part of the green movement and that have committed to weaning themselves from traditional oil-based fuels. This will give TMC enormous global strategic advantages in hybrid and fuel cell technology, production, and marketing.

Strategically Connecting Smart Products with Smart Design and Smart Operations

Hybrid propulsion systems rely on sophisticated software to manage the interface between the electrical part of the system, including capturing the energy normally lost during braking and the fuel-based engine. This embedded IT is part of TMC's vision of the smart car that also includes sophisticated electronics to help drivers know where they are (navigation systems) and to actually help drive the car ("Toyota's Approaches to ITS" [Intelligent Transportation Systems]) because TMC's management recognizes that the product needs to keep up with technology and people's life styles.

At the same time, the approach requires that when new technologies emerge that TMC can quickly incorporate them into its products with efficiency and reliability. Thus there is an integrated strategic connection between its smart product strategy and its smart design and production strategies that in turn depend on an organization that is cost and quality driven. TMC's ability to reduce design and production times to approximately 18 months for a new model has been well researched (Rapp 2002 And Fujimoto 1999) and need not be repeated here. What is important is how this ability enables TMC to quickly incorporate product improvements into new models while reducing cycle times. Better cycle times between client orders and ultimate delivery reduce costs and improve business forecasts since projections are for shorter periods. Similarly, more rapid design cycles more quickly incorporate the latest technologies into new model cars. Therefore, customer satisfaction is improved through more timely completion of the sales process as well as constant product enhancement. One example of this use of IT to improve competitiveness through faster cycle times is TMC's new parallel and buffer stock production system that permits it to reduce assembly times compared to the traditional

continuous assembly track approach (Rapp 2002 and Fujimoto 1999). IT inputs are critical factors in TMC's overall business strategies with strong positive competitive results for it and potentially negative implications for its competitors.

Controlling Quality, Intellectual Property and Global Supply Chain

Long before the introduction of hybrids TMC had integrated its global plant support into a total support system for the firm; this included its overseas affiliates and various suppliers. That system is also coupled with the company's overall operations including parts and steel ordering. In addition, TMC has used IT to economize on traditional production systems and inventory practices, such as the amount of steel that must be held for various automobile models. Hybrid development has been gradually integrated into this system, which is so tightly integrated that when Ford tried to develop its own hybrid, it found that the only available suppliers for certain crucial parts of the system were part of TMC's global supply chain, giving TMC tremendous strategic leverage.

In addition, TMC has been very astute in developing the Intellectual Property Rights related to hybrid technology. They have over 350 patents that are globally registered as well as a copyright on the critical software that controls the interface between the electrical-based system and the fuel-based propulsion system. Thus they have the ability to control the evolution of this technology during its critical launch period and well into the future.

Conclusion

A successful strategy must be sustainable over a period of years, and this involves the constant commitment of organizational and financial resources to implement and

evolve the strategy, especially in response to changes in the competitive environment. In a large, dynamic, global industry such as automobiles, this is a never-ending task. A company is able to maintain an edge over the competition by setting the pace in terms of product cost, quality, and innovation and by committing organizational and financial resources to sustaining this edge. TMC had already established its position as the leader in the first two elements through its lean production system that was well developed by the early 1970s.

It then changed and improved that system in the 1990s further reducing design and production times through the use of IT (Rapp 2002). While competitors were still trying to learn and adapt lean production, TMC moved its target to lowering design to 18 months and producing a standard car in 10 hours, all while increasing plant flexibility and further improving quality wherever the car is produced. As a result it continues to be the global low-cost producer for a given quality of car from a Corolla to a Lexus, in all of its plants. This gives its tremendous global pricing power. Furthermore, its lower warranty costs reduce the potential cash drain after the car is sold. The ultimate financial result has been global leadership in profitability and the building of a substantial cash horde.

Beginning in the 1980s, it began to strategically focus on the third element - the product itself. The hybrid is part of this strategy, though by no means the only part. Electronics; telecommunications; and ITS, including navigation systems and driver-assist, are important aspects as well (Rapp 2002 and Rapp and Islam 2004). Competitors such as Mercedes have struggled to respond to these electronically-based initiatives. Yet the hybrid represents perhaps an even greater competitive and strategic challenge to TMC's major competitors because of the resources that will be required are so much

greater while many are struggling with profitability, redundant labor, and obsolete plant capacity. In addition, TMC controls the intellectual property over many aspects of the hybrid's development and evolution.

Several TMC advantages seem clear. TMC may be the only major auto manufacturer to have the financial resources needed to fully develop hybrid technology across a range of products on a global basis, including the development of a hydrogen-based hybrid system, which will initially be used for public transportation. Second as it is already the established low-cost quality producer of automobiles, one must assume that TMC can and will apply this same organizational capability for smart design and production to hybrids of all types. Therefore competitors can expect TMC to make rapid introduction of improvements with higher quality and lower cost. TMC is already in commercial production of its third generation hybrid (Lexus 400h) with the fourth and fifth generations ready for introduction in the near future.

Even as TMC continues to move ahead many major competitors are still debating if they should develop a hybrid, though most eventually conclude they must. But, unfortunately for the competition, it is a scenario that does not offer a significant competitive counter offensive. The problem is that TMC's rivals do not recognize the essential elements of the strategic threat, seemingly a replay of the lean production scenario. For years competitors denied a superior production method existed. By the time the realization was forced on them, the competitive frontier had already shifted. Given the industry's mind-set, TMC is likely to extend and sustain its global leadership advantage in hybrids, and the auto industry in general, well into the 21st Century.

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