Hybrid Car Creates Hybrid Organization:
Development of Toyota's First Pries Model and Limits that Traditional Development Organization at Toyota confronted

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Feb.2010

No.106

Feb 2010

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Abstract

Each function-based department inside a company is individually optimized in a way most favorable to its own department, but from the standpoint of the entire company, each department is not necessarily behaving in the best interest of the entire company. That is, the manager of each function-based department possesses a biased preference for his or her own department.

The manager of each function-based department holds private information about his or her respective department's fields of expertise and technological advances. Given this understanding, it may be advisable for the company's headquarters to delegate decision-making authority to the managers of these individual departments. However, if decision-making authority is delegated to individual departments or to the managers representing the interests of each of those departments, those departments may pursue their own interests even at the expense of the company's interests as a whole.

By contract, the product manager does not have private information but is thinking about the new product under development as a whole and thus does not have a biased

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preference. The question then, is, what kind of governance structure will serve as the optimal solution? When each manager possesses a biased preference for his or her own department, it is important to consider the impact that the allocation of formal authority and the information flow within the organizational hierarchy has on the organizational capacity for innovation.

This theme is developed and illustrated, using the case of development of Toyota's "Prius".

In the case of Toyota Motor, too, this point has been an important issue for a long time when planning its development organization structure. The development of the world's first mass-produced hybrid vehicle, the Prius by Toyota is one of the most successful examples of innovative product development in recent years. However, it has been hardly studied as to how such architectural innovation was possible within the largest organization in Japan. This paper argues at length the development process of the Prius and transfiguration of Toyota's development organization structure from the viewpoint of organizational economics framework. Development of the first Prius model by Toyota set the stage for adoption of a new development organization structure : the term-limited implementation of the new "Big Room" approach, which did bring about lasting changes to Toyota's organizational framework for vehicle development. It will be noted that concept design, or in other words interdepartmental coordination, was more important in the initial phase of development (the first six months), and thus, the "Big Room" structure was the development organization structure of choice for implementation. By contrast, after the initial six months, work on the concept design of the product development had been almost completed and interdepartmental coordination had become less important to the company compared with advances in the technologies for the engine and other component systems. For that reason, the development organization was transitioned to a more decentralized structure of governance, the conventional “chief engineer” structure. The new development organization is a kind of hybrid organization, which lies between "centralization" and "decentralization".

Furthermore, we touched upon the point that delay is costly in decision problems because it increases the lag upon which decisions are based, and evaluated the new development organization structure from that viewpoint, too.

The arguments made in this paper will presumably be of value as generalized recommendations for the shape of the development organization within large established corporations.

1. Introduction

It is rather difficult for large established organizations to register commercial success with the development of innovative products. However, in recent years there has been one example of this type of success, albeit rare even on the international level. That example is the development of the Prius hybrid car by Toyota Motor Corp. The story of this Prius development has been drawing much attention, not only within Japan but also internationally, as one of the most successful examples of innovative product development in recent years (Iemura,1999 ; Ikari,1999 ; Itazaki,1999 ; Liker,2004; Egawa,Reinhardt and Yao, 2006 ; Tsukamoto,2006). However, there are few theses or studies that analyzed this story from the standpoint of rationality of the development process or the development organization structure.

Toyota is the largest corporation in Japan. Nonetheless, given that the Prius was the world's first mass-produced hybrid car, it stands out as an example of highly innovative product development in a short period of time. On top of that, it was an example of a development accomplishment that has had an enormous impact on business structure not only at Toyota itself, but throughout the entire global automobile industry. In effect, the Prius has to a significant extent become a powerful counterexample to the notion that architectural innovative product development is beyond the ability of large-scale established corporations. An even more intriguing feature of this particular development case is that it was spearheaded by Toyota, which pioneered the “chief engineer” model, an established model of governance structure that has been successfully implemented by the automotive industry up to now. Toyota had never traditionally been reputed to be an innovative company. The company had rather been criticized for multiplying fairly similar types of cars. Toyota's customers, if anything, belonged to the high age group, and Toyota did not have a very strong appeal to the young generation. Although Carolla of Toyota has been one of the best selling cars, the main reason for customers' choice of Carolla has been the reasonableness of its price (Egawa,Reinhardt and Yao, 2006).

Identifying organizational structures that are successful in the pursuit of innovative product development may be one of the most significant themes that researchers in organization theory have addressed in recent years. Generating new ideas alone is not enough to ensure the commercial success of an undertaking in product development.

Although internal ventures (firm within a firm) and skunkworks may excel at generating new ideas, there is a limit to the technologies and skills of each of the specialized sectors forming their core, like engine. Furthermore, they may face resource constraints in terms of their manufacturing and marketing capacity and other functions essential for commercial success. These are reasons why huge success in the arena of product development is not that easy to achieve. On the other hand, while an organization of sufficiently large scale typically will have an abundance of the functions essential for commercial success, the internal organizations of a company and top management are all separated by barriers that slow decision-making and communications, foster internal biases, and make it difficult for the company in its entirety to register desirable accomplishments (Bresnahan, Greenstein, and Henderson, 2007). Even at companies that are not very large, problems of this kind become common once the company has attained a certain level of corporate scale (Foss, 2003).

In the final analysis, the development organization will always face a trade-off between interdepartmental communication quality and decision quality of function-based departments. Accordingly, the way in which the organization deals with its operational setting and controls this trade-off will largely determine whether its development work is successful or not.

In effect, it amounted to a reasonably convincing refutation of the notion that the creative development of bread-and-butter product lines is difficult for large corporations to accomplish. Especially, established firms often have a surprising degree of difficulty in adapting to “architectural innovation” because much of what the firm knows is useful and needs to be applied in the new product, but some of what it knows is not only not useful but may actually handicap the firm[1].

The development of a jet aircraft can be cited as a representative example of architectural innovation”The jet engine initially appeared to have important but straightforward implications for airframe technology. Established firms in the industry understood that they would need to develop jet engine expertise but failed to understand the ways in which its introduction would change the interactions between the engine and the rest of the plane in complex and subtle ways.”(Henderson and Clark,1990, p17)

There seems to be a similar aspect in the development of the hybrid car as in the development of the jet aircraft, as both are thought to have a strong tinge of architectural innovation. This is because, although the development of the hybrid car is conducted based on technologies for each component for conventional gasoline-powered cars (In fact, there was even an idea within Toyota of loading hybrid engines on Camry, an existing gasoline-powered car, at the initial stage of development of the hybrid car.), there are significant differences in interactions among various components. The following is an example of such differences in interactions among components.

The hybrid technology is a technology to combine good features of gasoline engines and those of electric motors.. Electric Motors are efficient when accelerating rapidly. In contrast, gasoline-powered engines are not efficient when accelerating but become efficient once they reach a certain level of rotation. Consequently, the gasoline-powered engine sometimes stops by itself while a vehicle is running. And then, when the engine starts again by itself, it trembles just naturally. However, since the trembling may occur at unexpected timing to the driver, it could give a far more uncomfortable, uneasy feeling to the driver even if the degree of the trembling is the same as that you get when the driver starts engine of a conventional gasoline-powered

[1] Define innovations that change the way in which the components of a product are linked together, while leaving the core design concepts untouched, as “architectural innovation” “Radical” innovation establishes a new set of core design concepts embodied in components that are linked together in a new architecture. The distinctions between radical and architectural innovations are matters of degree. (Henderson and Clark,1990)

engine car himself. How to solve this problem? If you follow the way of thinking about the development of conventional types of cars, you will never be able to find a solution to this problem, because the driver gets a hateful feeling against the trembling because the engine starts moving at unexpected timing to him, despite the fact that the same degree of trembling is occurring as before. Even if we claim that this is a problem to be solved by the engine department, it may not be solved at the level of the engine department. Thus, in this case, Uchiyamada, who assumed the position of chief engineer for the development of the first Prius model, appointed a specialist on trembling studies as the leader of the task team to tackle this problem and specialists in engines as staff members to support him, unlike the conventional way of doing, and furthermore added specialists in control technology to the staff. And furthermore he told the specialist on trembling, "(Even if this is a matter of engines,) you should be the leader and lead specialists in engines and people in the vehicle testing department."

Accordingly, the most intriguing point about this development of the Prius was the fact that it had been driven by the innovations not of some new entrant in the industry, but of Toyota itself, an automaker with an established business model for success in the arena of product development.

In pursuing this innovative undertaking in product development, what limits did the traditional development organization at Toyota confront? What new frameworks did that organization adopt in the process of surmounting those limits, and what was the justification for their adoption? Finally, why did these new frameworks thereafter have a permanent influence on the structure of Toyota's development organization? Finally, we seek to determine how the allocation of formal authority within the hierarchy of the development organization influences the organization's capacity for innovation. In this paper, these questions are addressed from an organizational economics-based perspective with close attention to the factual details. Enlisting an organizational economics perspective for a comparative analysis of the organization prior to, during, and after the Prius development project, the arguments made in this paper will presumably be of value as generalized recommendations for the shape of the development organization within large established corporations.

2. Development process of the first Prius model and changes in development organization

(1) The Biginning of Hybrid Car Development

Toyota's initial foray into hybrid car development began with its "G21 Project" (Global 21 Project). The impetus for the G21 Project came around 1990 when Eiji Toyoda, then Chairman at Toyota, began insisting that with the end of the 20th century now approaching, the time had come for the company to begin seriously thinking about the types of car models it should offer the world market in the new century just ahead. However, because everyone at Toyota was busy with other things, no one immediately came forward to accept this challenge. Nonetheless, Toyoda continued to reiterate his plea over the next several years. Eventually, Yoshiro Kinbara, Vice President in charge of development was no longer able to ignore this and finally suggested forming a team for the purpose. The project thus took form as a study group in September 1993. At that stage, all members of this study group belonged at the same time to other departments where they were performing their main tasks, and about 30 people participated to the study group. As the study proceeded, it generated considerable interest, leading to the recommendation that a full-time specialist be assigned. The specialist role was assigned to Takeshi Uchiyamada in January 1994. Considering that the first Prius model was to enter mass production and go on the market at the end of 1997, the intervening development phase was surprisingly short, lasting only around four years. However, developing a hybrid car model was never the objective of the G21 Project at its outset. In fact, the project had two goals. One was to explore what a 21st-century car should be like. The other was to try a new approach to car development that changed certain aspects of the development methodology as then applied. Uchiyamada reportedly was given only these extremely ambiguous instructions and then ordered to work out the details on his own[2].

The G21 Project had been assigned the mission of exploring what cars should be like in the 21st century. Initially, the project team took on that theme with the goal of finding solutions to at least one of the problems likely to confront the 21st century's car-based society. However, in doing so, the team was also interested --at a minimum-- in maintaining, or even improving, the fun and conveniences that cars had provided society over the preceding century. Finally, as an outcome of study concerned with issues that the car-based society of the next century would absolutely have to overcome, the team ultimately focused on the issues of resource use and environmental degradation, and crash safety. At that time, crash safety was already considered to be a serious challenge within Toyota and was something the company was working hard to address. The project team felt that the company could make progress toward improving the crash safety of its vehicle lines even without the active involvement of the team. Environmental problems, however, were not yet being openly addressed and some even argued that investment in environmental measures would not lead to profits for the company. Nonetheless this was an issue that would have to be confronted in the next century. Given that understanding and the potential for new oil shocks in the years ahead, the project team came up with a concept that would be one answer to these environmental issues.

When the company's top echelon of executives had the concept explained to them, they accepted it with virtually no resistance and then ordered the team to explore ways of translating the concept into a commercial product. Around the summer of 1994, the G21 project team drew up a plan for one of the more challenging objectives at that time:

[2] In the background of Eiji Toyoda's insistence to initiate the Project, there seems to have been the following economic environment. At that time, due to the appreciation of yen in the foreign currency exchange market, there was a situation where even Toyota would not make any profi. Thus, its Finance Department was tightening spending in the entire company as much as possible. Technology Department was also asked to restrict overtime work in order to reduce costs, and employees were told to utilize already existing things with brains, instead of undertaking any money-consuming new projects. However, if such instructions are given, people cannot have dreams as engineers. Under such circumstances, a proposal to contrive a new type of car based on a totally new concept by utilizing every technology in hand was coined by Kiichi Inoue, General Manager of Merchandise Planning Department, who perceived Toyoda's intention and brought the Project to Yoshiro Kinbara, Vice President. (Statement of Kinbara, in Uchiyamada, 2003)

achieving a 1.5-fold improvement in fuel efficiency. That goal had been set so high that if Toyota achieved it, its rivals probably would not be able to catch up for some time to come. The team came up with a system that would be profitable even if replacing a car model already in production. As Uchiyamada recalls, "We were quite confident." In fact, the plan was conditioned on utilizing a conventional gasoline-powered model rather than a hybrid vehicle.

Namely, at that stage, Uchiyamada's intention was to achieve a 1.5-fold improvement in fuel efficiency, by combining a 1.5 liter direct-injection engine with a small combustion chamber and an automatic transmission based on high-efficiency manual transmission. His superior Kinbara, too, said, "When I was Vice President, I had never a thought about hybrid vehicles. I made a proposal to improve the fuel efficiency by 50 % and I understood that I was instructed to realize it. When I was asked about the type of the engine, I responded that it would be based on gasoline direct injection." (Statement of Kinbara, in Uchiyamada, 2003)

However, two of Toyota's management executives responsible for technical affairs, Akihiro Wada, who assumed the post of Vice President replacing Kinbara, and Masanao Shiomi, Managing Director, insisted that if the company were going to go through with these plans, then achieving a fuel efficiency boost of 1.5-fold would not be impressive enough for a 21st-century car. Uchiyamada recounts: "As engineers, this may sound like a gut-level comment, but personally it wasn't clear to me why a two-fold gain was considered adequate in the first place [laughing]. It's simply this. While a 1.5-fold gain in fuel efficiency was something most engineers would consider impressive, a two-fold gain was something anyone would have thought impressive. Certainly the average car customer would have thought so. That's why we have to achieve the higher goal." As engineers, Wada and Shiomi knew a two-fold gain in fuel efficiency would be difficult if not outright impossible to achieve with a conventional gasoline-powered car, and were fully aware this meant developing a hybrid vehicle. Both men consistently insisted that a hybrid vehicle should be the goal for a mass-produced 21st-century car model and asserted that if that step were taken, it would be clearly understood by the consuming public to represent a clean shift away from conventional car models and technologies.

In fact, Shiomi was at that time leading the R&D on hybrid engines within Toyota, in the capacity something like its sponsor. This very person Shiomi, who is the number one promoter of the hybrid engine in Toyota, told Wada about the hybrid engine, and Wada as Vice President in charge made a judgment that it should be the hybrid that could give a strong impression to the world.

However, Uchiyamada was resistant to that idea for some time, countering with two arguments: first, that hybrid engines were still in the R&D stage and not yet ready to put on the market as viable products, and second, that as project leader, he had to ensure that the project turned a profit but if hybrid technology were enlisted, the project would become too costly to be profitable. Ultimately, though, he was confronted by Wada, who said, "Look, if you don't want to go through with this, then quit if you like. However, we will get someone else to do it because it is something that has to be done." Uchiyamada recalls: "When the situation was put to me in that way, I began to feel I would have regrets if, having come this far, I couldn't be in charge of the development stage of commercial production." The decision was thus made to aim for the goal of a two-fold increase in fuel efficiency (with a hybrid car) and on that understanding, work started on the development of a commercially viable product[3].

(2) Organizational structure Stage 0 Departure from the Conventional Structure of the Development Organization: Persuasion by the Chief Engineer

The Prius development project introduced permanent changes to the organizational structure for product development at Toyota.

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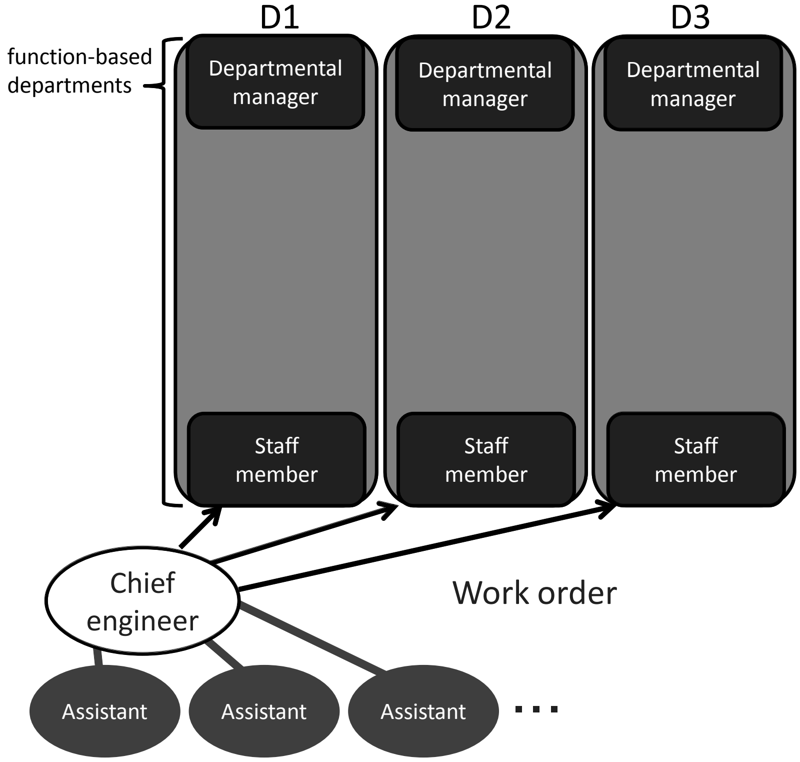
[3] Even after it was decided to pursue the development of the hybrid, Uchiyamada had been developing both of the hybrid and the direct injection engine at the outset. However, Syoichiro Toyoda gave instructions, saying, "If you try to achieve two things at the same time, you may not accomplish any of them, as a proverb says. 'Between two stools you fall to the ground'. Moreover, when you are going to realize a completely new 'hybrid', if you were studying in parallel a type of car with the conventional engine, the staff members would inevitably depend on the latter. Therefore, you should concentrate on the hybrid." and thus, the development was eventually focused on the hybrid alone.

Fig1

Changes in development organization
Stage0 -Conventional chief engineer system



・A chief engineer has formal authority within the authorized funding and man-hours.

・But, even after formal authorization of a project, staff members never leave their respective function-based departments. Individual staff members participate in multiple projects.

・Prior to formal authorization of a project, the chief engineer has to persuade departmental managers to cooperate with him or her.

some 30 years that Toyota has enlisted its project general manager or "chief engineer" system. However, prior to formal authorization of a project, the chief engineer typically has to explain to function-based departments why their human resources are needed despite the fact authorization has yet to be granted. At Toyota, in that case,the chief engineer is expected to convince others why his project is so important that he needs to borrow staff members from their departments. For this reason, chief engineers at Toyota have traditionally taken great pains to persuade departmental managers to cooperate with them.

As regards the G21 Project as well, at the beginning when it was launched in 1994, this type of Toyota's traditional development structure was adopted. Generally, architectural innovations can somehow be dealt with within the traditional framework of the organization in question at their initial stage (Henderson and Clark,1990). Therefore, it tends to take a long time for organizations with good achievements before they recognize a specific innovation as an architectural innovation. This is one of the reasons why architectural innovations often cause problems to organizations with good achievements.

Uchiyamada, however, gave up this Toyota's traditional development methodology immediately. When Uchiyamada received instructions to actualize the project in 1994, the G21 Project had not yet have authorization as a formal project from the company. For that reason, function-based departments were reluctant to provide cooperation, saying, "We are quite busy with many other things. Why should we loan out our human resources for a venture that had not been assigned a formal project status?", says Uchiyamada, recollecting the situation at that time. As a matter of fact, it was at a much later time, in June 1995 to be precise, when the development of the Prius was formally given the status of a formal development project of the company.

However, in respect of projects prior to formal authorization, these kinds of arguments have been taking place quite often within Toyota vis-à-vis each function-based department. Then, why the conventional development structure was abandoned for the first time in the case of the G21 Project?

The first reason, among others, was because the development of a hybrid vehicle would demand the development of a set of entirely new technologies, and as such, the related burden of coordination could be expected to be extraordinarily heavy compared to past projects for conventional car models.

Yet, the more fundamentally important point was the following second reason, which takes root in the more fundamental argument as to how to dissolve the problem relative to Toyota's conventional development structure, which had gradually been becoming ostensible at that time.

Before taking charge of the G21 Project, Uchiyamada was in charge of the administration of Technology Department for two years and was working on the review of Toyota's R&D organization under Yoshiro Kinbara, Vice President (He is the person who accepted first the task of leading the G21 Project). According to Uchiyamada, the development organization of Toyota, which was formed based on many years of efforts, is basically an excellent one, but a number of problems have also been unrevealed.

The most serious problem is that each function-based department is individually optimized in a way most favorable to its own department, but from the standpoint of the entire company, each department is not necessarily behaving in the best interest of the entire company. That is, the manager of each function-based department possesses a biased preference for his or her own department (conflicting preferences). This is in fact a serious problem, and Uchiyamada states that he could observe various problems in detail at the development arena from a department in charge of administering Technology Department, at a distance. Uchiyamada says, "I have observed such phenomena in many corners of our R&D organization that virtual walls isolate function-based departments from one another, and that even if certain things seem apparently desirable for the company as a whole, it is not easy for each function-based department to give concessions that should be made in light of such desirable things. Thus, I thought that I would not be able to accomplish my project with the traditional way of doing, namely with the negation-based approach when I assumed the post of leading the G21 Project." As regards the G21 Project, too, "I received a lot of complaints. People said that Technology Department was dissipating money as it likes at this financially difficult time.", recollects Uchiyamada. "Who was on our side, besides Technology Department, was Kiichi Inoue, General Manager of Merchandise Planning Department, only, who had proposed the very Project." (Uchiyamada, 2003) Kinbara, who was the superior of Uchiyamada in the administration section of Technology Department states also as follows: "People in Engine Department do not like to see the weakening of engines and they tend to think of engines before anything else. In fact, however, they also need to think about the entire Technology Department and the entire company. Toyota is a company selling cars but not engines. Thus, in order to improve cars, you need to review the organizational structure, even if (for instance) Engine Department should pay some cost for that purpose." (Statement of Kinbara, in Uchiyamada, 2003)

Uchiyamada states further that Toyota's development organization has become so large that decisions and communication take time and much time is required before new products see the light of day.

Companies can hardly recognize by themselves that the architecture of their products has changed with a lapse of time. Therefore, it is necessary to consciously undertake studies of architectural changes or studies of new interactions among components, and constantly take that matter under careful consideration. For the studies of new architecture, however, there are cases where new types of organizations and/or human resources with new types of skills that are different from the past are necessary. Uchiyamada's career record was fairly atypical for a person appointed by Toyota to serve in a chief engineer's position.

Assuming chief engineers at Toyota still operate the way they always have, a person in that position has to know which strings to pull within the company to get their project moving in the direction they desire. Consequently, chief engineers are most often selected from among staff members with experience as assistants to chief engineers. However, Uchiyamada had no experience as a chief engineer or its assistant at all. In fact, mechanical engineering was not the area of specialty that he had studied at university. His academic background was in applied physics with a specialty focus in automated control, an area that Toyota at the time did not even have any employee openings for. Uchiyamada was initially hired by Toyota only because he had visited the Toyota recruiting office asking to take the entrance exam for employee candidates on grounds the school research lab with which he was affiliated at the time had not received any recruiting materials from Toyota. Because he was a student at a lab that Toyota had no plans to recruit new employees from, and at the time was educated in automated control technology, a business field Toyota did not handle, the company was probably puzzled as to how it could utilize Uchiyamada's skills and thus decided to place him on its computer software development team. In that position, his duties involved developing computer software for technical applications in the technology department.

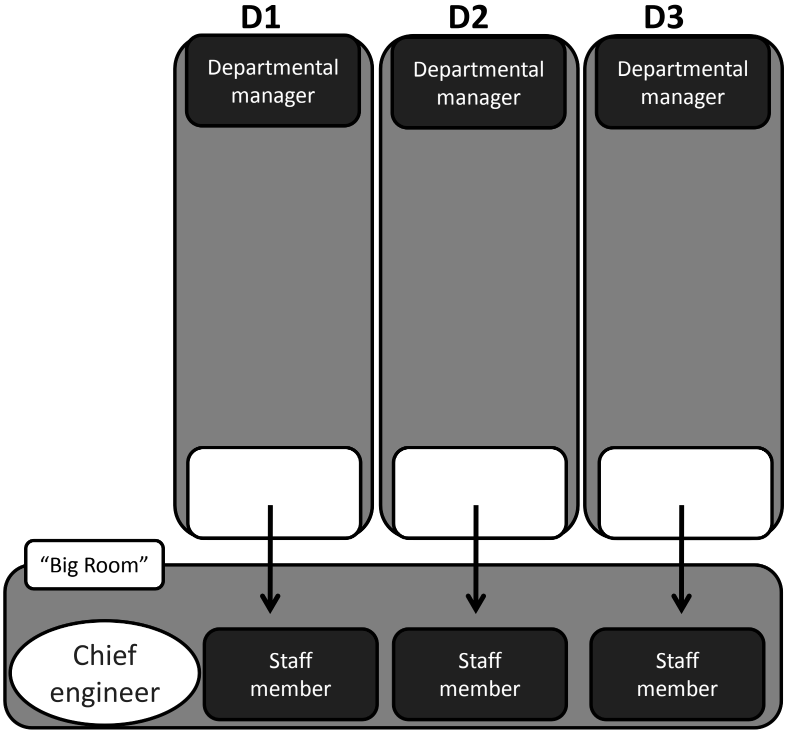
Why, then, was Uchiyamada selected to serve as project leader for the Prius development project? From the start, the primary goal of the G21 Project was to develop a new car model suited for the 21st century. However, that project had another goal: namely, to discover a new and as-yet unknown approach to automobile development that differed from the conventional approaches utilized to date. (At least this was the initial explanation given to Uchiyamada by Kinbara that notified him he was being transferred.) Uchiyamada states that he was not consciously striving from the outset to make any changes to the way Toyota develops its new cars but instead had to make those changes out of sheer necessity. And on that point, he notes: "Because I had no knowledge of the conventional development methodology, I was able to achieve what I did because I was scared of nothing."

(3) Organizational structure Stage 1(the beginning of 1994 to June 1994): The First Six Months: Shift from Chief Engineer-based Persuasion to the "Big Room" Approach

By force of necessity, this state of affairs gave rise to the idea of setting up an independent team capable of handling a certain amount of study on its own. This was the forerunner to the "Big Room" approach, as it was later dubbed within the company. Specifically, it was decided that a team of 10 staff members would be assembled in a large room to handle the stages from product development to pre-production preparations. The team would have its own room, and was to include staff members in

Fig2

Changes in development organization
Stage1 –"Big Room" approach



- Self-contained team is capable of handling the stages from product development to pre-production preparations.
- The team has its own room.
- The team has a limited amount of time to operate, and the function-based departments loan staff members to it for that amount of time.
- Those staff members work exclusively for the development project for the vehicle in question.

outstanding staff members to it for that amount of time and treat them as if they were on sick leave. Because he had spent two years in a managerial position in a technical department, Uchiyamada knew many people inside the company and nominated five of the team's 10 members himself. He asked the departments to submit candidates of their own for the five remaining positions and had "a good friend" in the personnel department check whether the candidates so chosen were actually highly qualified staff members or not. As a result, all of the team's members proved to be highly motivated individuals capable of conducting fairly extensive independent research within the team setting. (Fig2)

In effect, under the traditional approach to vehicle development at Toyota, new models were developed one by one in coordination with the function-based departments involved. However, for development of the hybrid car, the project team had one staff member each supplied from the function-based departments as necessary for a limited period of six months. Thereafter, the process of study and research was a responsibility of the team itself, and for the ensuing six-month time span, the team was not to coordinate its efforts with any of the function-based departments. Afterward, the departments would be asked to discuss proposals the team had put together[4].

Under the conventional approach, the chief engineer serves as an indirect channel of communication when information flows from an engineer affiliated with one function-based department to an engineer from another department. By contrast, the framework of new "Big Room" approach has the benefit of facilitating direct communication between the engineers themselves, encouraging a smoother exchange of

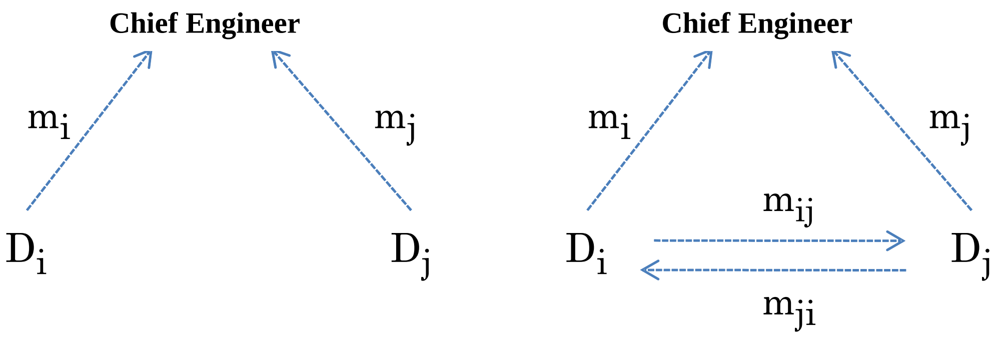
[4] The team accepted responsibility for all research and study over the initial six-month period and did not issue a single progress report to any of the function-based departments during that time. It actually did request that the departments review and discuss the proposals it ultimately prepared. However, in reality, it appears team members did stay in touch with the managers of their respective departments and provide summary reports of project progress on an informal basis. It is assumed the reason for this is that such team members wanted to maintain close working ties with their coworkers in view of the fact they would have to return to their affiliated departments after six months.

At the end of the six-month period, departmental managers did not show much resistance when the team's proposals were presented to them for discussion. Two reasons can be cited for this. First, it is surmised that team members maintained a certain level of informal contact with their respective departmental managers, as indicated above. Second, departmental managers were able to view the team effort as a training exercise for younger staff members because, compared to past situations with the conventional approach, their departments supplied only marginal human resources to the project.

soft information based on message exchange. (Fig2-2)

Fig2-2 .　　　Differences in the Flow of Information

Conventional Chief Engineer svstem　　　　**"Big Room" approach**



D_i; i function based department　　　　m; message

"Big Room" has a chief engineer who works together with a team of working-level engineers assigned exclusively to the development project for the vehicle in question. One distinguishing feature of this model compared to the conventional approach is that each of the engineers on the team is responsible only for duties related to that vehicle development project. Under this governance structure, the engineers on the team leave their respective function-based departments and report directly to the chief engineer. We can notice here another advantage of the "Big Room" approach. That is, in the case of the conventional approach, because engineers maintain a strong sense of belonging to the function-based department they belong to, they are influenced by the biased preference of their department, resulting in partial optimization. By contrast, in the case of the "Big Room" approach, because engineers are organizationally separated from the function-based department they belong to, they are rarely influenced by biased preferences of the function-based departments, and from the standpoint of the entire company, they can devote themselves to the achievement of development objectives for a new type of vehicle.

Despite the fact that most Japanese automakers including Toyota had been moving in general to strengthen the role of their product managers (chief engineer), they did not utilize a project execution team model like this "Big Room" approach, except for emergency projects and other extremely unusual cases[5].

Why was a project execution team model like the"Big Room" approach not implemented by Japanese automaker? In noting the reasons for this, Clark and Fujimoto (1991) made the following comments based on the outcome of their study: "Their worst fear was that engineers with specialized roles [in function-based departments] would be spread out and placed into full-time positions in a single [car development] project, resulting in a loss of accumulated expertise [in the core technologies that function-based departments commanded]. They preferred the conventional product manager model that enabled individual working-level engineers to participate in multiple projects." (Chapter9:text in brackets added by author.)

We refer to this loss of accumulated expertise in a core technology as a "dilution cost." It is necessary that technological advances in function-based departments be more highly valued and protected when advances in a core technology are vital. When it is the case, a project execution team model like "Big Room" approach was shunned because it implied higher dilution costs and because automakers preferred organizational structures that stressed function-based departments. This same point can help explain why the "firm within a firm" or skunkworks (teams of highly autonomous engineers assigned the mission of generating new ideas) approaches are prone to failure.

The U.S. automaker Chrysler Corp. went a step further than its Japanese counterparts and actually implemented an approach akin to the "Big Room" approach , and ultimately experienced failure in that undertaking. In the early 1990s, Chrysler adopted its "platform team system," which assembled a dedicated team of professional members for each of the company’s base models and put those teams in their own big rooms for development (Fujimoto, 1997, p. 275). At the outset, this approach helped to

[5] As examples of emergency projects and other special situations, Fujimoto (1997) cites Honda's effort to meet revised "kei-car" (ultra-light subcompact car) standards with its "Today" model and the development of Mazda's Eunos Roadster model (p. 275). The Honda project was completed in only one year and the Mazda project, in only one year and half.

drastically cut development project lead times and demonstrated significant benefits. Eventually, though, it failed and the dilution costs outlined above were the reason for that failure. For example, the engine engineers involved only had their minds on engine for a given model developed by the teams with which they were affiliated. No one was thinking about the evolution of engine technology as a whole.

On the other hand, because implementation under the "Big Room" arrangement in case of the Prius development project is time-limited, it does not interfere significantly with the environmental adaptation of individual function-based departments and thus has few drawbacks. Drawbacks that were a justification for not applying the project execution team model such as "Big room" approach in the past were readily overcome by limiting the time frame for application. Although this may have been a coincidence attributable to the force of necessity, it is clearly an innovation in the structure of the development organization[6].

The Prius hybrid-car development project provided a crucial opportunity to use the "Big Room" approach. Since then, that approach has found widespread use in many of Toyota's new car development projects and has fostered lasting changes in the structure of Toyota's development organization for new car models. "It was quite new that this level of dialogues [dialogues among engineers belonging to different function-based departments] are made at the initial stage of product development. This became the model for the subsequent development of new cars." says Toshiharu Ishida, who was one of the members of the G21 Project (Egawa ,Reinhardt and Yao, 2006) .

(4) Organizational structure Stage 2 (June 1994 to October 1997): Shift back to Conventional System and the Adoption of Promotion Meeting.

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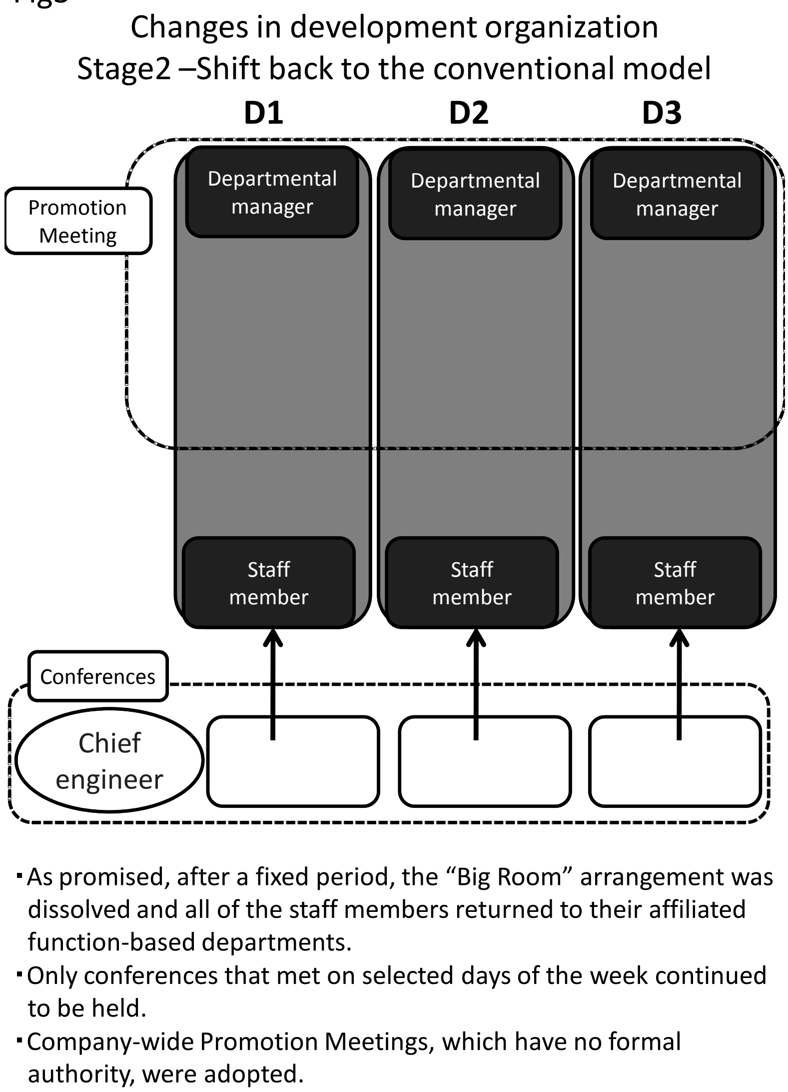
[6] Honda, not Toyota, has been sometimes called the founder of the "Big Room" approach as implemented in Japan. To be sure, Honda has a track record of formally issuing instructions for its engineers to work as members in "Big Room". However, such instructions notwithstanding, it has not required that its development project members actually physically assemble in the same "Big Room". Physically speaking, they remain at their desks in the function-based departments where they normally work. In real terms, this approach is understood to be not that different from the "Chief Engineer" framework that Toyota developed. Honda's "Big Room" approach is not conceptually built around the "Big Room" approach in case of Prius project. It can not be interpreted as an attempt to facilitate the exchange of soft information among project members.

As promised, after six months, the "Big Room" arrangement was dissolved and all of the engineers that had been on loan returned to their affiliated departments. In other words, the development framework shifted back to the conventional "Chief Engineer" model. Only conferences that met on selected days of the week to discuss specific themes continued to be held.

However, the cost of coordinating the working-level engineers (who had returned to their posts) with their departmental supervisors became higher after shifting back to the conventional framework. Because the development project's members (the working-level engineers) continued to share ideas with one another, all were clearly aware of the specific tasks that they were responsible for within the project, but relations with middle management in the function-based departments became more problematic. Owing to the possibility that departmental managers and middle managers in the function-based departments would feel as though they were being kept in the dark about the project, development team members ended up spending an inordinate amount of time coordinating with them. For example, when subordinates delivered operational reports to the managerial staff, they were asked why they were engaged in such work or compelled to listen to suggestions for ways of doing their work better. That was in a sense ill-natured treatment. Hence, even decisions that had already been settled by team members themselves were occasionally called into question again by these supervisors. As a consequence, team members found their workloads needlessly burdened by the expectation that they coordinate with departmental managers and middle management personnel in addition to coordinating with one another.

To address this problem, a decision was made to hold meetings with these managerial staff members present. This was the background to the adoption of company-wide Promotion Meetings. Ordinary directors are the highest management level attending these promotion meetings. Senior managing directors, vice presidents, etc. do not attend. Promotion Meetings are attended by members from not only technical departments, but also other departments throughout the company, including production, finance, and so forth. The company-wide Promotion Meetings at Toyota have no formal authority, whatsoever. Their objectives are to share information and coordinate management vectors. In terms of content, the impression is participating managers are told to refrain from making needless comments to individual engineers because that tends to inflate the related coordination costs. Instead, they are urged to use the meetings as a vehicle for the presentation of their own views, should they have any they wish to express. To be honest, the development team members were the most informed, at least with regard to the technical issues of the hybrid-car at the time. On such matters, directors and managers had nothing of value to say. Nonetheless, now, whenever development team members sought managerial consensus for something they wished to pursue, they already had departmental understanding and were no longer individually subjected to needless instructions or viewpoints.(Fig3)

Fig3



Even so, the meetings still had significance that extended beyond the solution of purely emotional or interpersonal issues. There was real value in having the departmental managers of function-based departments included in the promotion meetings. The reason was that these departmental managers possessed private information that no one else knew about. For example, they as well as middle-management staff members had information pertaining to recent trends in exhaust-gas countermeasures and other environmental regulations, trends in car design, and so forth. Because this was information on headline topics, it was advisable that it be shared so that team members involved in development of the hybrid car could take it under consideration as soon as possible. Hence, the company-wide promotion meetings served as a framework to facilitate a smoother transmission of messages pertaining to private information held by departmental managers and everyone under them. Prior to the development of its Prius model, Toyota had a ceremonial promotion conference that had been set up to help its directors save face. However, compared to the company-wide promotion meetings, this conference had little if any real value.

(5) Influence on the Post-Prius structure of Toyota's development organization

The term-limited implementation of the "Big Room" approach as described above did bring about lasting changes to Toyota's organizational framework for vehicle development. That is not to imply, however, that it had been intended to cause significant changes in development procedure itself. The changes that took place were implemented because circumstances forced their implementation. Against the backdrop of an international wave of measures to mitigate global warming, the top management at Toyota demonstrated an urgency toward development that in turn put pressure on the development process. In other words, the stringent constraints imposed by a short lead time starkly highlighted the limits of the existing model of governance structure and had the effect of setting the stage for the debut of a new governance structure.

The deadline to start commercial production of the Prius was revised several times, almost to an unusual extent, and each time it became shorter and shorter. Initially, then-company president Hiroshi Okuda,who assumed the post of President in August 1995, instructed that the new model be ready before the end of the 20th century (1999).

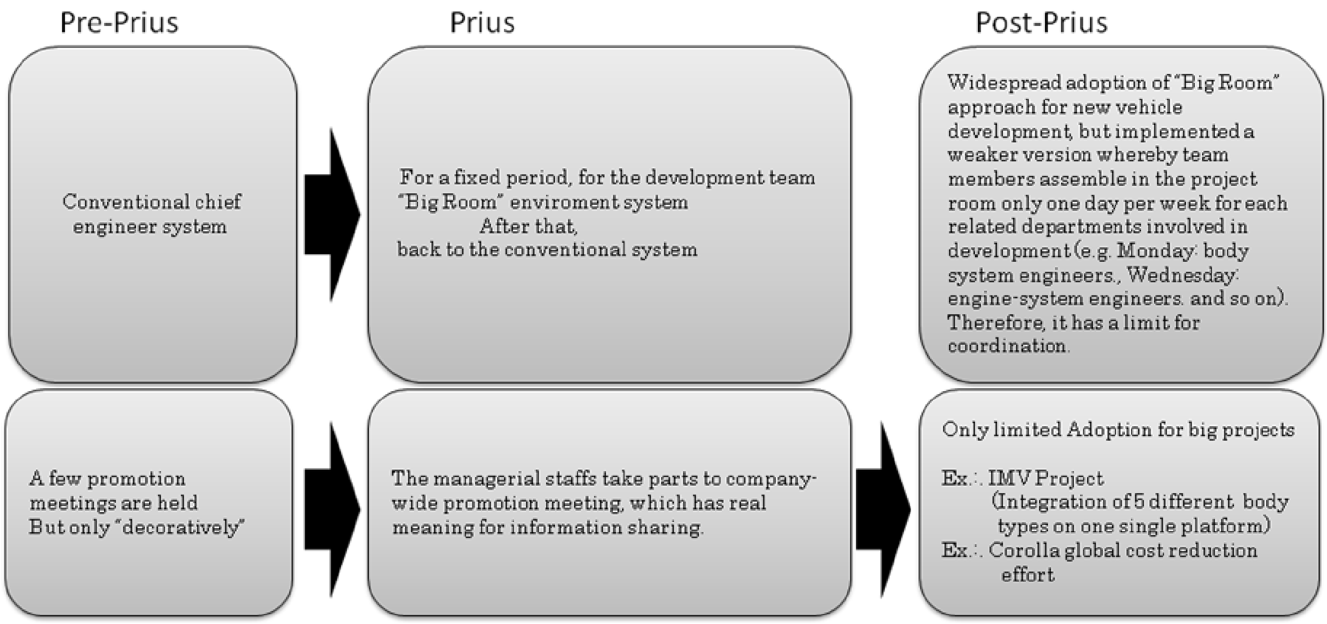
Acting in line with Okuda's expectation, Akihiro Wada, Vice President in charge of development, set a target date of December 1998, one year earlier, and notified the development team to that effect. However, President Okuda then issued additional instructions designating December 1997 as the new deadline. Although Vice-President Wada protested that there would not be enough time, President Okuda overruled his objections. At this time, the development team made one request of the president. They declared they would aim for a December 1997 deadline and noted that the development process would experience several milestones, and requested that the product launch be delayed beyond the end of 1997 should any uncertainties of a technical nature, including questions of product reliability, arise as a result of evaluations conducted when they reach those milestones. This resulted in a consensus. In other words, the development team started their work with December 1997 set as the target deadline for the first car to roll off the assembly line, and with the understanding this target would be pushed back if it proved too tough to meet. As noted earlier, when this project got under way in 1994, it had not yet received internal authorization as a formal project, and as a consequence, function-based departments did not readily submit to team requests for cooperation because in their view, they were not being asked to contribute resources to a formally approved venture. However, given the unusually short target deadline set for the Prius' commercial launch, there was no time to follow standard internal procedures. Hence, as a matter of necessity, the project leader, Uchiyamada, came up with the idea of creating a team that could independently handle much of the required study on its own.
In reality,however,Toyota could achieve the mass production of the Prius in October 1997,two months earlier than scheduled.

Looking back, he noted that setting a short development time frame actually proved to be a good thing, for had it been any longer, the work of the project team might have dragged on without ever getting the car into production.

Although, in the years since the Prius was developed, the "Big Room" approach has undergone a number of variations in response to development project scale. In addition to the aforementioned time-limited type that was applied in the development of the first Prius model, Toyota has also implemented a weaker version whereby team members assemble in the project room only on selected days of the week. With this latter approach, team members in reality have physical access to the room facilities at all times and on visits to the room, are always able to examine information about the new car development project of their own. And engineers specialized in a given area may assemble for meetings on, say, just one day of the week: for example, body system engineers on Mondays, or engine-system engineers on Wednesdays. This selected-day format becomes dominant because it is believed to have been implemented as one of the ideas aimed at preventing significant interference with the environmental adaptation of function-based departments. But this format clearly has a limit for coordination among the function-based departments.

Also, after the first Prius model had been developed, company-wide promotion meetings sometimes came into use for large-scale projects at Toyota, too. For example, promotion meetings were adopted for the IMV Project (a project aimed at placing five different car bodies on the same chassis platform) and a global cost-reduction program for the Corolla model.(Fig4)

Fig4



3. Organizational Economics-based Interpretation about the Changes in the Development Organization Structure

(1) Allocation of formal authority

When each manager possesses a biased preference for his or her own department, it is important to consider the impact that the allocation of formal authority and the information flow within the organizational hierarchy has on the organizational capacity for change (Aghion and Tirole, 1997; Baker, Gibbons, and Murphy, 1999; Alonso, Dessein, and Matouschek, 2008; Rantakari, 2008). The holders of local information are the individual departments within the company. The nature of the changes that the organization should undergo will be dependent on the full body of this information held by individual departments. Given this understanding, it may be advisable for the company's headquarters to delegate decision-making authority to the managers of these individual departments. However, if decision-making authority is delegated to individual departments or to the managers representing the interests of each of those departments, those departments may pursue their own interests even at the expense of the company's interests as a whole.

If we confine the argument to the development of vehicles, the manager of each function-based department holds private information about his or her respective department's fields of expertise and technological advances, and product manager of the developed vehicle is not aware of that information. However, from the standpoint of developing a new vehicle that is useful for the company, the manager of each function-based department has a biased preference. By contract, the product manager does not have private information but is thinking about the developed new vehicle as a whole and thus does not have a biased preference. The question then, is, what kind of governance structure will serve as the optimal solution?

In the case of Toyota Motor, too, this point has been an important issue for a long time when planning its development organization structure.

Development of the first Prius model by Toyota set the stage for adoption of a new development organization structure. Though the conventional chief engineer structure exemplified modeled Toyota's development organization prior to the Prius, following the start of the Prius project, the development organization temporarily adopted the “Big Room” structure for a limited period and then transitioned to the chief engineer and company-wide Promotion Meetings structure.

In this Section 3, we attempt to examine such questions as "Where, to begin with, did exist the rationality for the conventional chief engineer structure of Toyota Motor having been adopted?" and "Where did exist the rationality of such a model being shifted to new development organization structures including the "Big Room" approach, taking the opportunity of the development of the Prius?", by studying at length the transfiguration of Toyota's development organization structure from the viewpoint of organizational economics framework.

(2) Rationality of Conventional “Chief Engineer”structure at Toyota

The conventional “Chief Engineer” structure at Toyota has been the successful model of governance structure that Toyota devised and that came into widespread use not only among automakers in Japan but worldwide. The product manager in this case (“Chief Engineer”) has direct contact with working-level engineers, wields strong powers of direct and indirect influence over all project-related function-based departments and operations, and has responsibilities in the areas of product planning and conceptualization (Clark and Fujimoto, 1991 ; Fujimoto, 1997).

But in relation to our own research objectives, it raises questions about where the scope of authority retained by the chief engineer ends and where the scope of authority delegated to function-based departments begins.

On that point, in this paper, we attempt a detailed analysis of the internal allocation of formal authority under the existing Toyota approach, the paradigm as implemented by Toyota starting in the 1950s, earlier than any other Japanese automaker[7].

To state a conclusion first, in terms of organizational economics framework, the structure of Toyota's vehicle development organization does "centralize" formal authority in the hands of chief engineers, to a certain limited scope in advance. That scope is delineated by limits or constraints on the formal authority that individual managers of function-based departments have over the affairs of their respective departments. One important characteristic feature is that chief engineers at Toyota have formal authority over matters pertaining to the vehicles for which they are responsible, and the scope of that authority is such that the managers of function-based departments (e.g., managers of the body design department or the engine department) have no formal authority of their own. In other words, formal authority of a predefined scope has been concentrated or centralized in the hands of the product manager ("Chief Engineer").

The actual process of concentrating formal authority in the hands of the chief engineer and the scope of that concentration are as follows. Whenever a development project is given the go-ahead at Toyota formally, the chief engineer will be allocated a certain number of man-hours and a budget to cover development costs (for example, 500,000 man-hours for body design and 15 billion yen for total development). Within these boundaries, the chief engineer can issue written work directives "shijisyo" (formal work orders) to the working-level engineers in a given function-based department without obtaining approval from that department's manager. Because these are formal work orders, they cannot be overridden or ignored. However, decisions as to which of their working-level engineers may be used still rest with the managers of function-based departments. Chief engineers do not have the formal authority for that. Should a chief engineer wish to utilize a specific individual, he or she will have no recourse other than to negotiate with and persuade the manager of the department with which that individual is affiliated.

Generally speaking, there are different models of governance structure are

[7] Toyota's success spurred the adoption of the conventional “Chief Engineer” approach by other automakers worldwide from the mid 1970s through the 1980s.

conceivable. : 1) Authority over the affairs of each function-based department has been delegated to the manager of that department (Decentralized authority). 2) Authority over the affairs of all of the function-based departments is held by the product manager (Centralized authority). 3) Authority of a predefined scope has been concentrated or centralized in the hands of the product manager (Partial centralization)(Rantakari (2008)). And the "chief engineer" structure at Toyota is considered to belong to the "partial centralization".

Accordingly, the routine job of a chief engineer is to utilize and put to work as his own subordinates those working-level engineers from function-based departments that have been allocated to his project. However, when the chief engineer judges that an engineer under his supervision faces a technical problem that is beyond that engineer's ability level, he will consult with departmental managers and in some cases, with company executives. The decision to take this step is at the discretion of the chief engineer himself. Unless he has good judgment, his development project could face the risk of becoming bogged down.

The chief engineer is typically supported by three to five assistants. Assistants are chosen as candidates for service as future chief engineers and have ranks as section chiefs or higher. However, they do not represent function-based departments with which they were affiliated. Although they may be affiliated with different departments, a relatively larger number of assistants are chosen from the car design or chassis design departments in view of their ability to read design blueprints or technical drawings. The traditional approach to the training of chief engineers resembled the apprenticeship system. Many chief engineers and their assistants were affiliated more often with the car design or chassis design departments and less often with the engine design or other components design departments or the testing department. However, Takeshi Uchiyamada, the employee chosen to serve as chief engineer for the Prius project, was affiliated with the testing department, marking an exception to the general rule. What is more, he had no experience whatsoever as a chief engineer's assistant. That is to say, he was not an individual who had received the training he would have been expected to receive under the traditional apprenticeship-like system for chief engineers. Whether the choice was intentional or not, it conversely had a side-benefit in allowing Uchiyamada to pursue an all-out, systematic development venture precisely because he had no background knowledge of Toyota's conventional approach to product development. In fact, Uchiyamada was told by Yoshiro Kinbara, who had been Uchiyamada's superior in the administration section of Technology Development Department that, as the leader of the G21 Project, Uchiyamada, who is not an expert of the conventional approach, is most appropriate.

To summarize, within established quotas of, say, XX hours for Department A, YY hours for Department B, and ZZ billion yen for the entire development budget, formal authority is concentrated in the hands of the product manager (chief engineer). This is the model of successful conventional governance structure of Toyota's vehicle development organization.

Now we would like to compare this model for the conventional chief engineer structure at Toyota with other structural models and examine the rationality as to why the conventional chief engineer structure was adopted.

One of the structural models that can be compared with as regards the development organization structure for vehicles is the simple function-based organization. The organization structure exists at each departmental level and there are no individuals in the organization that have broad horizontal responsibility for any product development project in its entirety. This would be a typical structure of "Decentralized authority", where formal authority has been allocated to the manager of each function-based department in the organization[8].

In the meantime, we can also find a different model from that of "chief engineer" structure at Toyota, among structural models where a product manager in the organization exists. The product manager for a given product development project handles the coordination of working-level engineers either directly or through liaison officers. Toyota's chief engineer structure is the one, directly handling such coordination,

[8] This portrays an organizational structure such as that enlisted in the past by Mercedes Benz and other European automobile manufacturers.

and the model that can be compared with Toyota's model is the one, handling the coordination through liaison officers. The project manager in the latter case is sometimes referred to as "lightweight product manager" as he or she has a relatively weak coordination power, while the chief engineer at Toyota is sometimes referred to as "heavyweight product manager" (Clark and Fujimoto, 1991). The vertical relationships represent internal relationships within each individual function-based department while the horizontal relationships illustrate coordination relationships for specific product development projects. Individual function-based departments (e.g., the body design department, engine department, chassis design department, vehicle testing department) are supervised by their respective departmental managers. Liaison officers are simple contact points for their respective departments. By contrast, there are working-level engineers in positions of substance inside the function-based departments.

Because the lightweight product manager does not have direct ties to working-level engineers of "substance" and thus has less power than the departmental managers, the product manager has limited powers of influence particularly outside the product development related departments. He or she has quite weak responsibilities with regard to product conceptualization. Communication and coordination are the primary duties of the lightweight product manager. The rationality for the conventional chief engineer structure of Toyota Motor is owing to the background that a strong need for interdepartmental coordination was created, in order to materialize unique product concepts that draw attention of, satisfy and please users and to realize outstanding product development performance.

However, one point we must give special stress about lightweight product manager model here in connection with the objectives of our own research is as follows. In terms of organizational economics framework, it is true that there is no characteristics of centralized arrangement at all because individual function-based departments retain formal authority over their own affairs completely (“decentralized authority”) while product managers are given no authority whatsoever. On this point, lightweight product manager model is significantly different from conventional chief engineer model at Toyota. Naturally, under lightweight product manager model, coordination on products to be developed will be weaker. Conversely, however, individual function-based departments will be better able to adapt to their respective environments. In terms of the relationship to automobile development organizations, suffice it to say that internationally, the lightweight product manager model was once the most common structure observed to be in use among automakers prior to the spread of Toyota's conventional chief engineer model.

(3) Why was the "Big Room" approach introduced, taking the opportunity of developing the Prius?

Note that the aforementioned models of governance structure are marked by increasing levels of integration as one move from a simple function-based organization to the lightweight product manager model, then the “chief engineer” structure at Toyota, and finally the "Big Room" approach.

If we apply an organizational economics framework, the following analysis is possible.

For the purposes of simplification, the organization consists of two function-based departments and one product manager(headquarters). The manager of each function-based department possesses assorted field-specific information about which the product manager is unaware (private information). However, from the company's perspective, the manager of each function-based department possesses a biased preference for his or her own department. Consider the problems of coordination between two function-based departments, i and j. Expressed as an equation, i's preference is

$$\Pi_i = K_i - k_i((1-r_i)(\theta i - d_i)^2 + r_i(d_j - d_i)^2)$$

where d_i and d_j respectively stand for decisions made by departments i and j.

$r_i \in (0, 1)$ is a value expressing the relative importance of coordination with department j to department i (Rantakari (2008)). $\theta i \sim U[-\bar{\theta} i, \bar{\theta} i]$ is an expression for the environment faced by department i, and the value of this expression is private information known only by the i's departmental manager . Each departmental manager is in a position to issue a (nonverifiable) message $m_{i,} m_j$ of some kind that will enable him to use this environmental information to his own advantage.

That is, first, sender learns the state of the world, θ. Second, sender chooses a message, m. Third, receiver gets the message and chooses a decision, d. Fourth, payoffs are decided. This game allows for a perfect Bayesian equilibrium (when the player's own beliefs are the basis for predicting moves by the other player, each move needs to be optimal and the beliefs need to be correct at the equilibrium). If the problem is formulated in this way, the objective will be to identify the functional relationship to desirable governance structure when the characteristics of each function-based department are treated as givens. Each function-based departmental manager learns the environmental conditions affecting his or her own department, strives to communicate with the personnel that have formal authority, and considers what information content (message) to convey to that personnel. Afterward, a decision will be made by the person with formal authority. By taking into consideration the strategic actions of each person, it is possible to endogenously and simultaneously determine both the quality of decisions made on the basis of available information and the accuracy of the information conveyed when the allocation of formal authority within the organization and the environmental conditions are treated as given. In such cases, the structure of communication within the organization can be modeled with the game-theory concept of a "cheap talk" game (Crawford and Sobel, 1982; Gibbons, 1992) ; Alonso, Dessein, and Matouschek, 2008 ; Rantakari, 2008). Depending on the governance structure implemented, there will be a trade-off between the "coordination" of individual operations within the corporation and the extent of environmental "adaptation" achieved by each function-based departments.

When the parameters are altered, the way in which the equilibrium organization structure changes will be key. The conclusion here is that when r_i is a large value (signifying a strong need for interdepartmental coordination), a structure of more centralized authority (as in the "chief engineer" structure at Toyota) or the "Big Room" approach is desirable, whereas when r_i is small, a structure of more decentralized authority (as in a simple function-based organization or the lightweight product manager model) is desirable. The significance of this conclusion is that choices made when allocating formal authority within the organizational hierarchy are influenced by a trade-off between interdepartmental communication quality and function-based departmental decision quality. That is, when interdepartmental communication quality is more important, the "more-centralized authority" model will be chosen, and when function-based departmental decision quality is more important, a "more-decentralized authority" model will be the rational choice. From an organizational economics perspective, the implication is that the " more-centralized authority" model of the development organization is the optimal choice when, in terms of developing a new car, the relative importance of coordination with function-based departments (r) is fairly high and, from the standpoint of the function-based departments concerned, the relative importance of coordination with the car's development team (r) is low. The findings of this economic analysis seem consistent with the development organization structure which automobile industry created. In other words, the fact that Toyota's "chief engineer" structure or the "more-centralized authority" model had spread among automobile makers in the world from 1970s to 1980s and become more dominant compared with a simple function-based organization or the "lightweight product manager" model based on the "more-decentralized authority" model is owing to the background that a strong need for interdepartmental coordination was created, in order to materialize unique product concepts that draw attention of, satisfy and please users and to realize outstanding product development performance, amid ever intensifying, dynamic, competitive environment of the automobile industry.

Then, notwithstanding the situation where the integration of Toyota's development organization structure seemed to have stopped with the adoption of the "chief engineer" structure, why did the development of the first Prius model set the stage for adoption of a new development organization structure, the "Big Room" approach?

Though the “chief engineer” structure exemplified Toyota's development organization prior to the Prius, following the start of the Prius project, the development organization temporarily adopted the "Big Room" structure for a limited period. This adoption of a new development organization structure or pattern succeeded in averting one drawback of the "Big Room" structure -- inflated dilution costs -- by limiting the period of time that the "Big Room" structure would be implemented. That is, during the initial development stage (the first six months in the case of the Prius), the desire for strong coordination among function-based departments took precedence over concerns for dilution costs because of the importance of concept design, among other factors, particularly in the context of innovative development project. For that reason, the "Big Room" structure was the rational choice compared to the conventional “chief engineer” structure. Once the initial development stage had elapsed, the benefits of divisional coordination faded and the dilution costs became relatively more pronounced, making the use of the "Big Room" structure irrational and the transition to the conventional “chief engineer” structure a better choice.

In effect, if attention is focused on the time path for r_i, it will be noted that concept design, or in other words interdepartmental coordination, was more important in the initial phase of development (the first six months) because the development project itself was of such a highly innovative nature. That is, for larger values of r_i, interdepartmental communication quality was more important than the quality of departmental decisions of function-based departments, and thus, the "Big Room" structure was the development organization structure of choice for implementation. By contrast, after the initial six months, work on the concept design of the product development had been almost completed and interdepartmental coordination had become less important to the company compared with advances in the technologies for the engine and other component systems. For that reason, the development organization was transitioned to a more decentralized structure of governance. In other words, Toyota adapted its development organization structure to a changed set of conditions whereby decision quality of function-based departments was more important than communication quality. And furthermore, the adoption of company-wide Promotion Meetings was chosen over the traditional “chief engineer” structure from among the more decentralized structures of governance because it better facilitated mutual message exchange.

However, if you take the matter under more elaborate consideration, you are able to say that there is not much difference between the "chief engineer" structure and the "Big Room" approach from the aspect of the difference in degrees of centralization of formal authority to the chief engineer (in other words, both approaches seem to be categorized into "partial centralization" to the chief engineer, more or less to the same degree). Nevertheless, more theoretical reinforcement may be required if you are to explain why the development of the first Prius model by Toyota set the stage for adoption of a new development organization structure; the "Big Room" approach. On that point, if we apply an organizational economics framework, the following analysis becomes possible.

When the information that an organization obtained has become old, and if the organization has to make a decision based on such old information, there is a risk that the situation and environment surrounding the organization has changed in the meantime. Therefore, the efficiency of the organization as a whole may also be assessed by the delay time between the point when the organization first obtained the information and the point when the organization makes a decision based on the information Delay is costly in decision problems because it increases the lag upon which decisions are based. Based on such a way of thinking, a group of studies called "team theoretic approach" within organizational economics have evolved (Bolton and Dewatripont, 1994; Garicano and Van Zandt, ; Radner, 1993; Van Zandt, 2003). It is said here that depending on the environment surrounding the organization (or depending on parameters), there is a possibility that the "freshness" of certain information becomes important.

If we apply the team theoretic approach to the development process of the Prius, we can say the following.

At the point of time of "Stage 0" before the adoption of the "Big Room" structure, working-level engineers belong to their respective function-based departments and excel in their respective functional expertise. Thus, at that point of time, they are possessed of the most up-to-date functional information at Stage 0.

However, at Stage 1, when the "Big Room" approach is adopted and first-class working-level engineers are selected from function-based departments and they leave their respective function-based departments to enter the "Big Room", they are now to report to the chief engineer of the Prius instead of their department managers. Thus, from the viewpoint of the freshness of possessed information, these working-level engineers are able to hold the most up-to-date product information about the Prius at Stage 1 (this is an advantage of the "Big Room" structure). On the other hand, as regards the functional information, they are possessed of old information at Stage 0 (information of one term earlier) only and such information is no more renewed (this is a disadvantage of the "Big Room" structure). Therefore, unless you limit the time span to adopt the "Big Room" structure, functional information held by these first-class working-level engineers gets older and older and the magnitude of disadvantage gradually exceeds the magnitude of advantage from the aspect of the company as a whole.

Thus, at Stage 2 which starts after 6 months of Stage 1, it becomes rational to dissolve the full-time "Big Room" and to send back these working-level engineers to their respective function-based departments. The above-stated story can be explained simply from the reason of computational delay, with no regards to the problems associated with incentives or allocation of authorities within the organization.

Because the pace of departmental technological advancement has become truly rapid in recent years, there have been signs of an internal trend toward shorter time frames for the "Big Room" approach with an earlier return to a decentralized structure (the conventional “chief engineer” structure) at Toyota. This can be considered a rational choice in terms of the economic models described above. This deserves recognition as an organizational innovation Toyota engineered through its Prius development program.

By the way, at Stage 2, when working-level engineers have returned to their respective function-based departments, they are not necessarily able to acquire the most up-to-date functional information at Stage 2 immediately. Should function-based departmental managers and middle-level managers possess the latest, functionally valuable business information about their departments and other private information at Stage 2, there is a risk that company's costs could escalate if the latest information were not utilized for the purpose of developing the Prius. Thus, in order to make the most of the latest functional information at Stage 2 for the development of the Prius as swiftly as possible, it can be understood that promotion meetings composed of departmental managers and middle-level managers in the function-based departments as members were created so as to share information. The promotion meetings do not have any formal authority. Toyota's creation of the promotion meetings encouraged information sharing, such that the formal authority held by departmental managers and chief engineers would remain intact as-is, and departmental and middle-level managers of function-based departments would utilize the meeting framework for the early submission of messages relating to matters outside their authority (i.e., matters over which chief engineers had control). In this way, Toyota both encouraged information-sharing while offsetting the drawbacks of the conventional “chief engineer” structure.

Efficiency accounts of the firm argue that the multidivisional governance structure arose and succeeded because it reduced costs by creating a clear distinction between strategic and tactical plannings. But examining new evidence in the paradigmatic case of General Motors ,GM intentionally violated the axioms of efficient organization to create managerial consent (Sloan, 1963). That is, the divisions become involved in long-term planning and performance evaluation through gaining representation on the committees dealing with overseeing governance (“participative decentralization”, Freeland, 1996). Although there is a difference between GM and Toyota in the purpose of information-sharing where in the case of GM, it is intended to share information possessed by individual operations segregated by the types of final products, while in the case of the promotion meetings of Toyota, it is intended to share information possessed by individual function-based departments such as the body design department, engine department, chassis design department, vehicle testing department and so forth, both companies are similar in the sense that they place an importance on the function of the interdepartmental committee, which does not have any formal authority but has the role in information-sharing and communication.

4. Conclusions

Success by Toyota Motor of the world's first mass-produced hybrid vehicle, the first Prius model, has drawn attention worldwide and changed completely the way of doing business by the automobile industry. However, it has been hardly studied theoretically and empirically as to how such architectural innovation was possible within the largest organizations in Japan ; Toyota Motor, and what impact the development has exerted upon the development organization of automobiles.

In this paper, we attempted to examine such questions as "Where, to begin with, did exist the rationality for the conventional chief engineer structure of Toyota Motor (before the development of the Prius) having been adopted?" and "Where did exist the rationality of such a model being shifted to new development organization structures ; the "Big Room" approach, taking the opportunity of the development of the Prius?", by studying at length the development process of the Prius and transfiguration of Toyota's development organization structure from the viewpoint of organizational economics framework. On that occasion, we attempted to perform an assessment from the perspective of organizational economics, and we particularly put our focus upon the problem of the occurrence of sectional optimization owing to the existence of a biased preference for each functional department and the way of changing such sectional optimization to corporal optimization and the ways of allocating formal authorities within the development organization of the company. Furthermore, we touched upon the point that delay is costly in decision problems because it increases the lag upon which decisions are based, and evaluated the new development organization structure from that viewpoint, too.

As a result, it was not only made clear that the new development organization structure is a kind of hybrid organization, which lies between "centralization" and "decentralization", but also that such a structure is rational from the standpoint of a product development organization. A main argument is that the development organization temporarily adopted the "Big Room" structure for a limited period of time. This adoption of a new development organization structure succeeded in averting one drawback of the "Big Room" structure -- inflated dilution costs -- by limiting the period of time that the "Big Room" structure is implemented.

Recollecting the first days of the development, Uchiyamada, who served as the chief engineer of the first Prius model, says, "I was quite worried that everyone engaged in the development of the Prius would conduct his or her work in the same manner as for vehicles equipped with conventional gasoline-powered engines, transmissions and other equipments, ordinarily developed by Toyota. I thought that, if they follow the conventional way, the development of the Prius would never turn out successful." And he thus told engineers involved in the development of the Prius, "The development of new vehicles in recent years is being handled just systematically, but the development of our new car (Prius) will not be proceeded with in that way. We are just in the same situation as that where our forerunners of 2-3 generations before developed a new car some 30 to 40 years ago. We should therefore think as if we were back to 30 to 40 years ago, and we should not assume the posture that we knew everything. Let's anyway gather at the working place and think together how to solve the problem in front of a car with problems, by actually observing the phenomena."

The work processes and organizations in use by industry today are already optimized for the production of modern goods. That is why they are still in use despite gradual changes made over many years. Conversely, it follows that while they are not necessarily bad when it comes to the task of developing and producing new and innovative products that do not yet exist, our modern work processes and organizations may not always be ideal. One cannot develop an entirely new product unless one also devotes attention to new organizations and approaches for the task at hand. Further, success will remain out of reach unless this requirement is also recognized by one's peers

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