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I. Introduction

Toyota has been of interest to academic researchers for many years due to its interesting methods of manufacturing and management of product development. Among researchers whose work is cited in this research note are Fujimoto, Hino, Liker, Morgan, Spear, and Sobek. For the purpose of this research note, Toyota is viewed as interesting for several related reasons:

1. Toyota appears from the outside to be very good at what in the aerospace industry is called System Engineering. The main effect of this approach to product development in an automobile company is a focus on systems (collections of parts that perform important functions) rather than on the individual parts. In some car companies, it seems that there is a belief that good parts will make a good car. Attention to systems requires some definite fraction of the employees, perhaps 5%, to be willing to look beyond their immediate area to find out about related items and activities.

2. Toyota has carefully chosen what to outsource and what to keep in-house. By Whitney's past observations, items requiring high technology or technical skill, either in the car or in the manufacturing process, are typically kept in-house. In many car companies, much of the technically challenging items or tasks are outsourced, leading to dependence on suppliers [Fine and Whitney]. These suppliers are very good at what they do but often cannot integrate what they do with what the car company and other suppliers do.

3. Toyota does not seem to reach for the most advanced technology available to or used by the car industry in general, either in design software or factory equipment, but tends to stay a bit behind in favor of relative simplicity.

[1] This document is a translation of an April 2007 Japanese language discussion paper (#2007-MMRC-160) available at <<http://www.ut-mmrc.jp>>.

The result is methods that look less capable to other car companies but which the average engineer or shop floor veteran can carry out without the need for (usually scarce) experts.

Whitney's research on the design processes for car doors has shown that doors are complex systems in themselves, containing nearly all the elements of a car except the power train: exterior styling, interior styling, glass, paint, operating mechanisms, safety, entertainment, and climate control [Whitney a]. Other than seats and the instrument panel, the customer interacts with the door more than with any other part of the car, albeit intermittently.

Doors are complex not only because they contain many technical components but also because they need to be designed to deliver a number of "attributes" of direct interest to the customer. Apart from safety, the most important of these are closing effort, wind noise, water leakage, and fit and finish (also called gaps and flushness). Designing a door to meet strict targets in each of these domains is difficult enough, but the problem is complicated by the fact that the attributes interact and/or and conflict with each other. In particular, better sealing to keep out noise and water will make closing the door more difficult. Predicting analytically how a door will behave in these domains before the door and car body exist is also difficult. If it is found that prototype vehicles do not meet the targets, delays can occur while the designs and associated stamping dies and other tools and fixtures are revised.

The main goal of the study on which this research note is based was to learn how Toyota addresses door design at a system and attribute level in both design and assembly and to see what outsourcing decisions Toyota has made. The authors have all visited many auto companies and plants. In 1991, Whitney visited Toyota in Japan among many companies in many industries [Whitney b] [Whitney c].

In general, what was learned on this study reinforced many things that are already known about how Toyota approaches product development, but many details were enriched with examples, especially related to doors. Morgan's PhD thesis, completed in June 2002, explains the main timelines of Toyota's development process as well as the way sheet metal parts and dies are designed and the essential role of Production Engineering in this process from the styling stage onwards. The PhD thesis of Sobek shows how Toyota values system thinking and promotes people who are good at it. The book by Hino explains how standardized processes were at the heart of Toyota's operating principles at the beginning of the company in the 1930s. This study confirmed that all of these practices are still in place in 2007.

II. Study Outline

In 2004 Whitney visited the body shop and final assembly line of Toyota's plant in Georgetown, Kentucky, and was able to observe door welding and assembly of unpainted doors as well as attachment of these doors to unpainted bodies and final adjustment of door fit near the end of the final assembly line. Consistent with this prior visit, the authors sought but were not permitted to tour the unpainted door assembly area in the body shop on this visit. Instead we were allowed to tour the re-spot welding line and final assembly area of Line #1 at the Motomachi plant. We saw painted doors receiving all their additional parts such as latches, glass, seals, and interior trim. The main point of interest during this tour is the fact that eight different car models[2], including minivans, sedans, and station wagons, are made on the same re-spot line and the same final assembly line. The rest of the visit comprised interesting discussions with managers and engineers of the door design and production engineering processes. The visit comprised about 9 hours spread over two days.

Our hosts from Production Engineering included Mr. O. (a highly respected senior manager in Production Engineering (PE) Planning), Mr. I. (also in PE Planning), Mr. Sa. (General Manager of the Vehicle Planning and Production Engineering Department within Vehicle Production Engineering), Mr. Su. (a Group Manager in the Interior/Exterior (I/E) Production Engineering Planning Division responsible for door PE), Mr. Um. (Project Manager for doors for one car program in the Interior/Exterior Production Engineering Planning Division, and Mr. G. (a new young engineer in Mr. Um.'s group who works in Europe but is in Japan for training). Our hosts from door design engineering were Mr. Ue. and Mr. Y., both from the Lexus product development center.

III. Design and Manufacture of Doors

A. The Role of Design Standards and Standard Design Procedures

One of the key features of product development at Toyota is the speed with which it can convert the Chief Engineer's concept into cars coming off the assembly line. While all car companies are doing this faster, Toyota seems to be faster than most. At the same time, quality has not suffered. The methods used to design doors share characteristics with the rest of Toyota's product development process. These have been discussed at length

[2] The model names are: Crown, Crown Majesta, Crown Estate, Mark X, Estima, Mark II Blit, Progres, Brevis. If the Crown Athlete/Royal is considered a separate model then the number of models would be nine.

by Fujimoto, Sobek, Morgan, and Hino, among others. Among the key features of the process are

- Standardized processes and designs
- A limited menu of choices for key components and metal materials and shapes, other than exterior styling shapes
- Close interaction between production, PE and design, including styling
- Highly skilled engineers and technically strong managers, all of whom spend 4 to 6 years in a given job before moving to another one
- Great depth of experimental knowledge about door (or other system) behavior, correlated with the menu choices so that there is limited uncertainty about how the door will behave before any prototypes are built to reduce or eliminate re-work
- Embodiment of the knowledge, data, design methods, and menu choices in thick books of standards and design process requirements
- Rigorous updating of these standards whenever a discrepancy is found between design expectations and actual behavior

As a result, there are, for example, few basic kinds of door architectures and only a few types of hinges, rear-view mirrors, and handles. There are also just a few types of door frames and they differ only in exterior appearance. Furthermore, ways have been developed whereby designers can estimate the effects of design changes, such as what the effect will be on closing effort, for example, if an additional seal is added or the seals are designed to compress more.

The reasons for approaching door (and other domain) design this way include avoiding proliferation of designs and methods, encouragement of long term learning about the chosen designs, avoidance of time-consuming surprises during prototype builds, and improvement in engineering personnel's skills without wasted effort. In addition, with as many as 10 car programs ongoing at the same time, there is no way the existing staff of design and production engineers could carry the workload if they did not work from standard designs whose behavior is basically known already. The accumulated knowledge extends well beyond how the doors will behave in use and include the most productive ways to build them in the factory. Typically, in the design of a complex system with conflicting goals, a lot of time is spent trading off one attribute for another, including goals for Design for Manufacture and Design for Assembly (DFM and DFA). Apparently these tradeoffs were made 5 to 10 years ago when today's standards and selected architectures were being established. According to the interviewees, there are now few surprises during prototype builds because the basic designs and manufacturing methods tend to change so little from one year to the next.

As described by Hino and reinforced during this visit, the standards are protected in two ways. First, major changes are controlled by committees headed by senior executives, and changes are rare. Second, any time a discrepancy is found between predictions and behavior, the standards are updated. Additional learning is protected and encouraged down the supply chain because approved parts tend to be used across car programs, and this tends to entrench incumbent suppliers, giving them ample opportunity to improve their quality.

The calculations that support engineers appear to be basic curve fits or first principles formulations, such as the energy dissipated when a door closes. Complex CAE may be available but such methods are not used every day by engineers. This approach seems consistent with what Whitney observed during his 1991 visit where he was shown simple but effective methods for evaluating stamping feasibility. No CAE was involved. Other car companies used much more sophisticated methods but Toyota emphasized that regular engineers could use their methods and trusted them because they were easy to understand. Also, Toyota has a specialist department called Evaluation, which contains a few engineers who are experts in closing effort, seal behavior, and so on. These people serve all the ongoing car programs and do detailed calculations or experiments when the standard calculations are either not sufficient or else a somewhat different design is being used that goes beyond the predictive power of the standards. Whitney guesses that today Toyota uses lots of sophisticated CAE to aid stamping evaluation but not on an everyday basis because the standards protect the designers from serious mistakes.

Mr Ue. was among many who said that Toyota's current procedures, standards and levels of predictability in door design stem from efforts begun in the mid 1990s. Yet Hino says that the tradition of running the company from standards dates to the 1930s. (A later section of this research note discusses this point in more detail.) From about 1995 to 2000, lots of effort went into revising these standards and knowledge bases for door design. Since 2000, the knowledge has been used and updated incrementally but not substantially changed. Some areas of knowledge comprise 20 or more years of accumulated experiments and evaluations on actual car programs, so the period from 1995 to 2000 represents a resurgence of an established method rather than a new approach.

B. The Door Design Process

1. Methods

As described by Morgan, the design process contains multiple main evaluation iterations of the design before the CAD data are released to the die production shops. An outline of the main steps in Toyota's product development process appears in Table 1. After this, the dies go through several iterations of "tuning," a process in which the dies are adjusted until the parts meet the design dimensions and tolerances. Only in rare cases are imperfect parts accepted into the final car, a process called "functional build" in the US car industry. The reason why the design dimensions are sought is that these are the dimensions prescribed by the design standards, from which the behavior of the car is supposed to be predictable. Using these dimensions reinforces the standard; deviating from them creates confusion, reduces confidence in the standards, and causes problems with documentation of the as-built condition. If deviations are necessary because the predictions were not borne out, the standards are updated.

Table 1: Outline of Flow of Product Development at Toyota

Advanced Engineering

- Development of New Components, Machinery, Structures, and Platforms

Product Development

- Concept Development (including styling)
- Product Planning
- Product Design
- Product Engineering (Prototypes, Performance, Functional Evaluation)

Production Preparation

- Production Planning
- Production Process Planning
- Production Equipment Planning and Procurement
- Build Mass Production Prototype
- Preparation of Production Processes (Work Stations)

Production

- Start of Mass Production

Hino says, and Morgan seems to say, that in recent years prototype builds of parts, subassemblies, and cars are made using the dies that will ultimately be used for final production. The study on which this research note is based corroborated the view espoused by Hino and Morgan.

Estimates of how long the various stages last differ, but there is agreement from Hino, Morgan and Fujimoto that the time from approval of the Chief

Engineer's concept to styling freeze is a little over a year, the time from styling freeze to release of CAD data to the die shops is 6 months or less, and the time from first dies to start of production is a little over a year but as short as 8 months in some cases.

During the design stage, the design engineers can usually tell if their design cannot meet the targets, because the standards will reveal this. Usually they do not propose designs that are unable to meet the targets. If design or styling wants to push into a new area, the Evaluation Department is called on to do special calculations or experiments. The Advanced Engineering Department will do this for more extensive exploratory designs or new technologies. Untried designs and technologies apparently are not used in new car programs.

Evaluation iterations are carried out by styling, design engineering, and production engineering working together. The factory manufacturing engineers are involved from time to time but mainly their interests are represented by PE. As the process goes on, suppliers are involved more and more. Since the standard design is expected to work to deliver performance targets, the main activity during this period amounts to ensuring that this design can be delivered with the required productivity and cost. The tradeoffs therefore involve manufacturability, not whether the design targets can be achieved. Several people said that the priority is performance quality first, then appearance quality, then manufacturability (that is, manufacturing cost and efficiency). In other words, the company believes that "the user comes first, the dealer second, and the manufacturer third." Since performance quality is most noticeable to the customer, and since PE is basically the guarantor of the ability of the actual physical product to deliver performance quality, PE has considerable influence during styling and engineering design.[3] Also, since appearance quality, for which PE also has responsibility, has a slightly lower priority than performance quality, some pressure on the plant to emphasize appearance (such as gaps and flushness between adjacent exterior parts) is reduced. As always, when there are tradeoffs, it helps to have consistent priorities.

As in all companies, power shifts around over time. This study found that some important outsourcing decisions are made with such influence in mind. Thus one reason why critical items like instrument panels and doors

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[3] Morgan compares Toyota with a "North American competitor" (NAC) and says that the NAC does not have people who do what such vehicle production engineers do at Toyota. Few companies in any industry except semiconductors, to the authors' knowledge, have the organizational structure or the capabilities that PE has at Toyota, and only in rare cases do manufacturing people have a strong influence on design. In semiconductors, product and process are essentially the same thing.

are kept in-house is so that Toyota can build up the technical and manufacturing management skills of its personnel. If an engineers' role was mainly to oversee and give guidance to suppliers, they would have too much power since the suppliers would do what the engineers told them. Keeping such designs in-house exposes the engineers to the full force of the tradeoff discussions with production and PE and helps maintain a balance in these critical and extended discussions.

PE or the manufacturing engineers are constantly seeking to detect a feasibility or cost problem. When they do so the PE personnel not only flag the problem but also strive to suggest feasible and reasonable changes. This means in practice that PE must understand how the design works. This dual capability of PE is discussed more in a later section.

As an enabler of this schedule, all main stamping dies are made at the Motomachi plant or Teihou plant (both located inside Toyota City), or by local suppliers. This makes it possible to tune the dies quickly. When production will be done at overseas plants where long shipping times are required, it is necessary to reduce the amount of tuning done at the overseas plant. When Whitney visited Toyota in 1991 he was told that die accuracy was within 20μ of the CAD data. Today it would seem to be closer because Mr I. said that essentially no hand finishing of the dies is needed, whereas in 1991 some was. All of this is consistent with observations from this 1991 visit as well as Whitney's general observations about outsourcing strategy at Toyota and other Japanese companies: the main strategically important technical knowledge and skills related to both product development and manufacturing (what Whitney b c calls the "infrastructure of product development") are kept in-house and nurtured.

2. People

Sobek reported on the importance of career paths at Toyota for ensuring that top managers had strong technical skills, including what he called "connection knowledge," meaning the ability to understand the car as a complex system of interacting subsystems. It is also well known that people stay in their jobs a relatively long time at Toyota (generally 4 to 6 years or more), compared to other car companies, especially US companies. On this visit, these points were confirmed and amplified. We learned that Mr. O.'s career path, mainly in PE (but also including some experience in the design function), began with 6 years in PE, followed by a period doing product engineering for plastic and press parts, 10 years doing development of in-house interior plastic parts production methods and production preparation, then various positions in PE planning performing vehicle cost planning and production planning. Mr. Su. started his career in the manufacturing division at Toyota in an engine plant, spending 7 of 10 years in casting technologies plus other assignments in block machining and quality improvement, then 3 years at a vehicle assembly plant focusing on assembly line plant engineering and equipment maintenance, then onto assignments in PE, consisting of 5 years planning assembly lines and 7 years (ongoing today) in door PE.

Mr. Su. calls himself a "player-manager" and says that all managers up to his rank (group manager) must play this dual role in order to be able to teach their subordinates how to do their jobs. This policy also ensures the technical competence of the managers.[4] Mr. O. said that perhaps 10 years ago a more typical "manager" philosophy was put in place but the result was that senior managers lost too much technical competence, so the player-manager system has been reinstated. Nevertheless, managers above Mr. Su.'s rank must choose whether to continue as player-managers or shift to a management position which has more of a "managerial" orientation. Chief Engineers in product development are chosen from people who take the player-manager path.

Mr. Su. oversees a group of 8 Toyota people including himself, plus 8 supplier representatives, 3 temporary contract engineers, and a number of technicians. He is one of 5 managers at this level in Vehicle PE, the others dealing with other segments of the car body. The division he is in, Interior/Exterior PE Planning, has about 40 Toyota engineers plus 20-30 supplier people. Within this organization there are 5 groups, which deal with planning, exteriors, doors, instrument panels, and interiors.

Vehicle PE is one of the core divisions for production engineering of vehicles and altogether it has about 600 people (180 Toyota engineers, 170 Toyota technicians, and 260 supplier representatives). Vehicle PE planning seems to have an additional role, described below, of integrating a number of the body manufacturing specialties and at the same time integrating them with engineering design and styling of bodies and interiors. In Toyota City, the company has an astonishing 8000 people in all of PE. There may be as many as 1000 in the US, and several hundred in Europe, where Toyota plans to have more. Table 2 lists the departments in PE.

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[4] Spear also describes this responsibility of managers to teach their people and calls it part of Toyota's "DNA." Hino also uses the metaphor of DNA to describe Toyota and provides historical evidence for how it was built up.

Table 2: Production Engineering at Toyota
(2 Shitsu [offices] and 23 Bu [divisions])

Koutei kakushin suishin shitsu [Office for promoting plant innovation]
Anzen kenkou suishin bu [Division for promoting health and safety]
Puranto enjiniaringu bu [Plant engineering division]
Seigi kanri bu [PE control division]
Seigi kaihatsu bu [PE development division]
Paatonaa robotto kaihatsu bu [Partner robot development division]
Seisan butsuryuu shisutemu seigi bu [Production logistics system PE division]
Keisoku gijyutsu bu [Measurement technology division]

(Vehicle area)
Sharyou seigi bu [Vehicle PE division]
Puresu seigi bu [Stamping PE division]
Bodei seigi bu [Welding and Painting PE division]
Kumitate seigi bu [Assembly and Plastics PE division]

(Unit area)
Youso seigi bu [Component PE division]
Yunitto shisakui bu [Unit prototype division]
Enjin seigi bu [Engine PE division]
Doraibutorein seigi bu [Drivetrain PE division]
Shashii seigi bu [Chassis PE division]

(HV / electronics area)
HV seigi bu [Hybrid vehicle PE division]
Hirose kikaku Kanri shitsu [Planning office]
Denshi seigi bu [Electronics PE division]
Denshi yunitto seizou bu [Electronics unit production division]

(Production equipment area)
Kouki kanri bu [Production equipment control division]
Mekatoro- shisutemu bu [Mecha-tronics and System division]
Sutanpingu tuuru bu [Stamping tools division]
Dai enjiniaringu bu [Die engineering division]

C. The Role of PE

The mission of Vehicle PE is to deliver a vehicle that is easy to build and achieves the quality goals, such as door closing effort, water leakage, and the other customer attributes. This is a difficult job because it spans two typically separate domains in manufacturing companies, namely engineering for customer attributes and manufacturing for low cost and high efficiency. Furthermore, PE does not actually directly do either of the functions. That is, it does not design the car and it does not build the cars or components in the factories on a daily basis. The overall product development process, as described above, is assumed capable of creating designs that meet the attribute targets but it is also necessary to achieve manufacturability, cost, and efficiency targets with respect to the actual physical objects that are produced.

Stamping and welding people, for example, look for problems in their areas, such as parts that can't be stamped or weld locations that can't be reached by the welding equipment. Discussions with the design department prior to freezing the CAD data start early and are ongoing, frequent, and intense. As mentioned above, no one can identify a problem without offering suggestions for how to fix it. This was described to us as part of "our company's culture," which was also described as "working together for the customer." In other companies, we were told, "targets seem to be driven down to manufacturing, which has to deliver them" and "Other companies seem to go to production without having met the attribute targets." Toyota people say that they do not do either of these things.

Each class of car has its own targets. These are set well above what Toyota thinks the market will regard as the minimum for that class, so there is a range in which tradeoffs can be negotiated. But generally the targets are regarded as requirements. These are hardest to achieve both in luxury cars because their buyers demand so much, and in low-cost cars because there are tight constraints on costs that may be devoted to solutions. Great cleverness and resourcefulness are required. Yet Toyota people are confident that they can reach the targets because they have done it for many years. A cost or weight increase may be the only solution but it is a last resort.

Since attributes conflict and since targets usually rise, this is a difficult process that gets more challenging every year. The "pain" is usually shared across the different manufacturing domains, and PE has taken on the role of negotiating among these domains before going back to engineering design with suggestions. PE's role with respect to the manufacturing domains seems appropriate since PE considers manufacturing variation and its effect on the targets. Variation can arise in any domain, so it is necessary for someone to look for the best way to solve problems independently of the interests of any one domain. This role equips PE to act as the interface back to engineering. How and when PE took on or was given this role is not known to us and was not a subject of discussion during this visit.[5]

In summary, door design is managed in two main ways: (1) standards, checklists, and limited menus of design alternatives are used to guide the design toward the right solutions from the start; and (2) strong representatives from PE are part of the design process, reviewing, finding problems, suggesting solutions, and generally being partners in coming up

[5] In general, the history of these arrangements is important to know. Both Hino and Fujimoto have written whole books about just this aspect of Toyota.

with the final design. This shared set of responsibilities extends through the die tuning process and into the launch of the new car. Toyota keeps in-house the main skills and technologies needed to sustain this process and employs personnel policies that encourage technical depth in its engineers and managers.

IV. Observations

A. History of Standardization at Toyota

Hino shows that several features of the above process have been part of Toyota since it was founded in the early 1930s by Kiichiro Toyoda. Kiichiro did several things analogous to what Sloan did at General Motors 10 years before, namely establish the structure and operating principles of his company. Many Toyota practices, including JIT and standardization, originated in the need to achieve higher quality, save money and save time, but have gained in strategic value over the decades. The company grew its skills in design, quality (at first embodied as durability, later as performance and appearance), and manufacturing. It documented its knowledge and expressed it as standards for all essential procedures in the company. This study and the academic research cited in this research note mainly reflect the evidence of standards and documentation in product development engineering and production engineering. Beyond this is the fact that the standards today embody a standard of behavior, namely that good behavior means adhering to the standards, reading the documents, being pro-active about suggesting improvements, and updating the standards when improvements have been found and verified.

There appears to have been some deterioration of the standards process in the heady days of the 1980s. This is the time when the "heavyweight program manager" approach was in full swing. Clark and Fujimoto and others have found that these program managers wanted their cars to be distinctive and optimally designed. The result was proliferation of parts and components, such as dozens of steering wheels and engines.[6] The market for cars in Japan began to decline in 1991. Serious problems emerged at Toyota and other companies around this time as exports also stopped growing rapidly followed by drastic yen appreciation. Toyota took steps to further reduce costs and re-establish standards discipline particularly in the area of

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[6] Cusumano and Nobeoka discuss efforts at Japanese automakers to tackle the issue of parts proliferation through more systematic sharing of components and technologies across models in the 1990s. See also related discussion on "fat product design" or the trend toward over-designing of parts and components at Toyota in the 1980s [Fujimoto].

simplifying product designs and reducing proliferation of different types of parts. By 1995 plans were in place or under way. Thus many of our hosts refer to the current state of standard designs for doors as dating from 1995 as though Toyota started over around that time. But apparently 1995 marked a return to a much older tradition.

Morgan's thesis is dated 2002 and represents observations made in 2000-2001 of a smoothly-running standardized process. By the time of this visit, 2007, the 1995 process has had 5 years to prove the validity of the standards and 6 more to refine and exploit them.

B. Production Engineering as the Integrator

This study was predicated on several assumptions, some of which proved accurate while others did not. The main assumption was that Toyota is good at system engineering. This impression was gained from prior research and visits to Toyota as well as research by Morgan, Sobek, and Fujimoto. This assumption remains intact. A derivative assumption was that doors require a systems approach because they embody so many challenging and conflicting requirements. This assumption remains intact but should be read in conjunction with the next derivative assumption, namely that Toyota has adopted explicit and conscious methods for balancing and trading off the attributes. This seems not to be the case. Instead, the basic tradeoffs decisions were made 10 or more years ago and embodied in design standards and manufacturing reconciliation methods that seem always to be able to meet the requirements, given sufficient discussion, cooperation, and ingenuity. Thus the term "systems thinking" does not seem to be common. Rather, the system engineering process has been internalized as the right way to behave, consistent with the culture of putting the customer first, working together, and adhering to the standards. Other specific and well-known methodologies, such as Design for Assembly [Whitney b], the Taguchi method, and the House of Quality (QFD), are not practiced explicitly. Instead, by means of experimentation, documentation, and continuous improvement, a set of workable design methods and standard design choices has emerged which together produce good cars.

Production Engineering, particularly I/E Planning and Vehicle PE, has emerged to play the role of system integrator, at least in the body engineering part of Toyota's product development process. Whitney's research on assembly over several decades has shown that design of assemblies and assembly process design can act as an integrator of product development [Nevins and Whitney] [Whitney d]. It is fascinating to see this in action at Toyota. I/E is in a position to face both ways. With regard to the separate manufacturing engineering skill domains like stamping and painting, it can act as a mediator, seeking the most effective set of suggestions to take back to engineering. Within the engineering design process it can anticipate the problems of the manufacturing domains, give the engineers early warning, and seek mutually satisfactory solutions.

In terms of management principles, what was described by interviewees (and is not widely discussed in the academic literature) is the extent to which typical principles of specific roles and responsibilities are not adhered to at Toyota. What was seen on this study is interpreted as comprising typically clear roles (A is a design engineer, B is a PE engineer) but untypically blurred or shared responsibility, especially responsibility for delivering the targets. There is a saying "When everyone is responsible, no one is responsible." But this saying is made with respect to the ability to find out whom to blame. It is not a management principle. Instead, we might imagine Toyota saying "When everyone is responsible, everyone is responsible." This accords somewhat with the idea of the "high reliability organization" (HRO) identified by social scientists and researchers studying system accidents [Weick et al.]. Here the idea is that complexity cannot be managed with overt procedures alone and instead everyone must be mindful of problems that could occur and help protect others from them. Toyota has adopted standards and documentation as the first line of defense in this complex environment but has developed shared responsibility as the second line. HROs are no different in either respect. Toyota does not use any of the customary terminology of the HRO community, but such terminology seems applicable to product development, as has been pointed out in an unpublished study [Whitney d].

V. Closing Remarks

This research note argues that Toyota continues to pursue basic strategic decisions and policies regarding the infrastructure of product development that have been in place for many years, some for decades. These comprise attitudes toward technology and people that encourage depth of in-house knowledge, recognition of the importance of understanding interactions among the elements of its complex product, and adherence to proven methods as a response to that complexity. These policies have led Toyota to be a strong company able to deliver reliable cars quickly, but also may have created a conservative culture. This is not the only business model for success in the car industry but it may be the best for a company addressing the mass market. A major challenge for Toyota is to grow rapidly world-wide while relying on a learning process whose time-constants are measured in decades.

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