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The Origin and Evolution of the "Black Box Parts" Practice in the Japanese Auto Industry

by

Takahiro Fujimoto
The University of Tokyo

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Takahiro Fujimoto
Associate Professor, Faculty of Economics, The University of Tokyo

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1. Introduction

The purpose of this paper is to explore the origin and historical development of so called "black box parts" practice in the Japanese automobile and parts industry. Black box parts system refers to a certain pattern of transactions in which a parts supplier conducts detailed engineering of a component that it makes for an automobile maker based on the latter's specification requirements and basic designs. In a sense, this is a kind of joint product development between a system maker and a component supplier in that the latter is involved into the former's new product development process.

Although the system is called in various ways such as "black box parts," "gray box parts," "design-in" and "approved drawings," it has been known as a prevalent practice in the Japanese automobile industry and one of the sources of its competitive advantages in recent years. It was also one element of the Japanese supplier system, that many of the US auto suppliers tried to adopt in order to narrow the competitive gaps against the leading Japanese auto makers.

Although the black box parts practice attracted attention of both researchers and practitioners internationally, its historical origin has not been much investigated by business historians. Published company histories of major Japanese auto makers do not seem to have described this aspect of supplier management, either. Thus, research on the historical evolution of black box parts system seems to be important for those who try to understand, transfer or adopt the practice.

In a broader context of the Japanese-style production system in the post-war automobile industry, historical study of the black box parts seems to provide an important insight on how the Japanese auto makers built core capabilities that consisted of their highly competitive system. The case of theblack box parts might enable us to better understand how historical imperatives, entrepreneurial visions, and learning process from other firms make impacts on evolutionary patterns of production systems and capabilities.

Based on the above argument, this paper will first describe the current practice of supplier involvement in the product development in the major Japanese auto makers, such as Toyota and Honda, as well as a brief literature survey. It will then examine the origin and historical evolution of the black box parts practice at Toyota and Nissan. The next section will focus on the supplier side by analyzing some preliminary results of a questionnaire and field surveys.

2. Current Practice of Supplier Involvement in Product Development

2.1 Basic Concepts

Let us first define some key concepts. Clark and Fujimoto (1991, chapter 6) classified transactions between automobile makers and their suppliers into three broad categories according to suppliers' levels of involvement and capability in product development. Figure 1 illustrates typical examples of supplier involvement in product development by using simplified information asset map. Three basic categories were identified here: supplier proprietary parts, black box parts, and detail-controlled parts. This classification is basically the same as the classification by Asanuma (1984, 1989): marketed goods, drawings approved (shoninzu), and drawings supplied (taiyozu). The magnitude of supplier involvement in engineering is higher in the former and lower in the latter[1].

(1) Supplier Proprietary Parts: The supplier develops a component entirely from concept to manufacturing as its standard product (shihanhin); the assembler simply order the item from the supplier's catalogue. In this way, the supplier carries out almost all of the developmental work for the component. Some of highly standardized components, such as battery, may belong to this category.

(2) Black Box Parts: Developmental work for the component is split between the assembler and the supplier. In a typical case, the former creates basic design information such as cost/performance requirements, exterior shapes and interface details based on the total vehicle planning and layout, while parts suppliers do detail engineering. It is not clear what fraction of the total work is done by the supplier, but a general consensus in our study seems to be roughly 70%. I general, many of the functional parts and subassembly systems belong to this category. As shown in figure 2, there are two sub-categories of black box parts: approved drawings (shoninzu) and consigned drawings (itakuzu).

(2a) *Approved drawings:* After the supplier is selected, it carries out detailed engineering such as drafting of parts and subassembly drawings, prototyping and unit testing. The car maker then reviews the parts drawings, test prototype vehicles using the parts, make sure that the requirements are met, and approve the design. In this case, the drawings are eventually owned by the supplier, which assures design quality and patents of the parts in question. That is, the supplier has to make engineering actions in response to field claims related to the parts. In exchange for this responsibility for quality, the suppliers enjoy a greater degree of design discretion for better manufacturability and cost reduction. Switching the suppliers between engineering stage and manufacturing stage is rather rare in this case.

(2b) *Consigned drawings:* Unlike approved drawings, final drawings are owned by the car maker, but detail engineering work is subcontracted out to the suppliers. The former pays the design fee to the latter as a separate contract, and is free to switch suppliers at the manufacturing stage. It is the car makers which takes responsibility for quality

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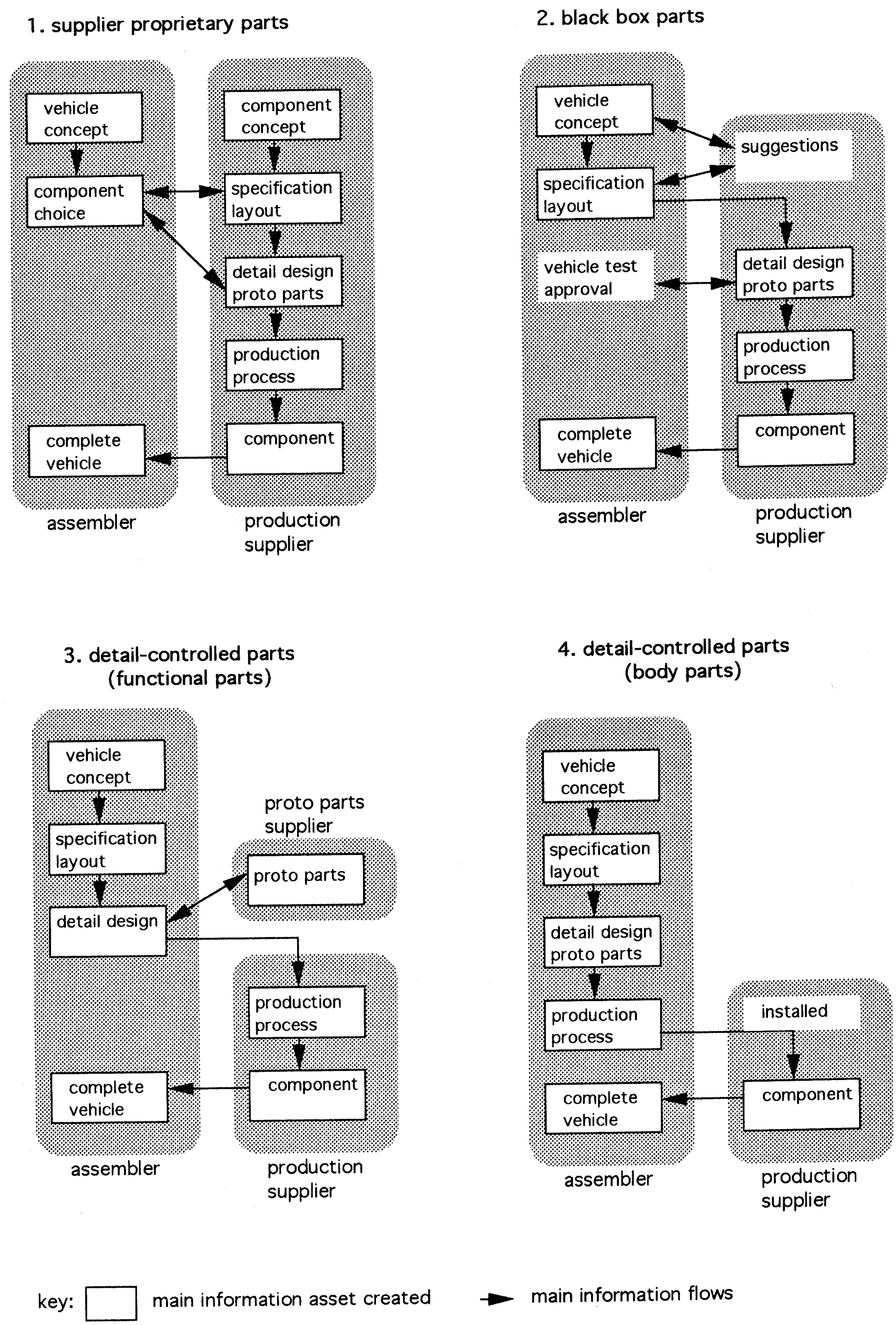
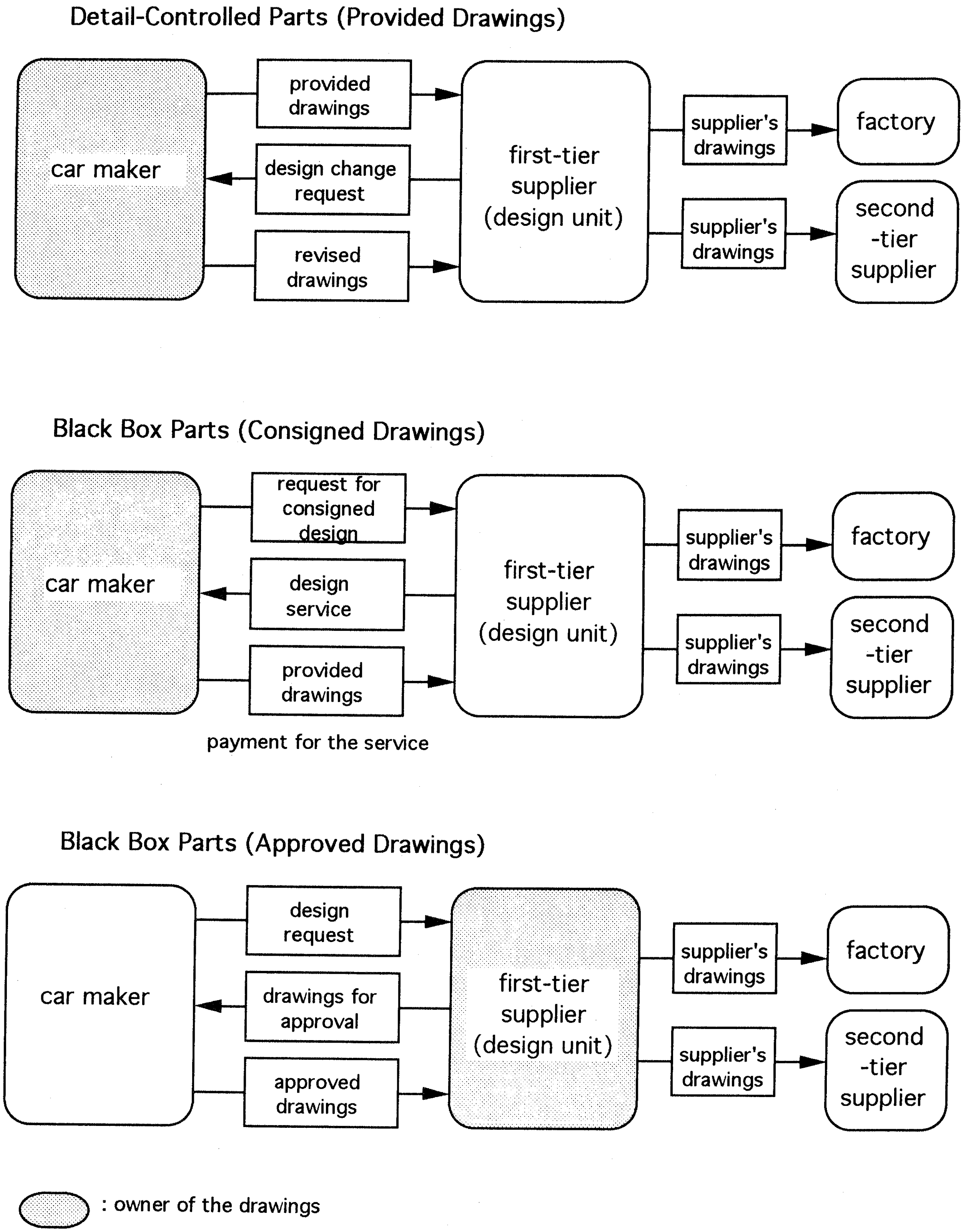
[1] On strength and weakness of each category, see Clark and Fujimoto (1991), Chapter 6.

Figure 1 Typical Information Flows with Parts Suppliers



Source: Clark and Fujimoto (1991, p. 141)

Figure 2 Basic Paper Flows for Each Mode of Transactions



Source: Company A (revised and translated by Fujimoto).

assurance, though. Many of so called "design-in" arrangements in the US in recent years are based on this system[2]. Overall, consigned drawings system is in between approved drawings and detail-controlled drawings in terms of the degree of suppliers' involvement in product engineering. While approved drawings tend to be applied to functional parts, consigned drawing system is found more often among press and plastic parts.

In the Japanese case, the information on the requirements may be provided to two or three potential suppliers, which compete for the job[3]. This selection process is called "development competition", which normally takes a half to one year[4]. Intensity of the development competition between the suppliers differ depending upon the parts categories: In conventional parts, the supplier for an old model tends to get a new contract for the new model; for technology intensive items such as plastic resins for bumpers, switching of suppliers take place more often, and development competition is severer[5]. The suppliers may initiate developmental actions and suggestions without waiting for the inquiries from the car makers. Also, as shown in figure 3, development competition occurs more frequently in the case of the parts for completely new models than in the case of model replacement (i.e., major model changes)[6]. In any case, the figure shows that development competition is more prevalent among the Japanese first-tier suppliers than bidding (i.e., the prevalent pattern of competition in the traditional supplier relationships in the US), which reflects the prevalence of the black box practice among them.

(3) Detail-Controlled Parts: The third category is the case in which most of the component engineering work, including parts drawing, is done in-house. In this way not only basic engineering but also detailed engineering is concentrated in the hands of the car maker, although the suppliers can make requests for design changes for better manufacturability and cost reduction. In the typical case of a functional component in the US, the suppliers, selected through inquiries and bids, take responsibility for process engineering and production based on the blueprints provided by the car maker. For this reason it is called "provided drawings (taiyozu or shikyuzu) system" in Japan[7]. Fabrication of prototype parts may be carried out by a different suppliers specializing in prototypes. In some cases of body parts, the car maker may also carry out process engineering, build and own tools

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[2] For example, a manager of a Japanese parts manufacturer (Company A) points out that Chrysler's Outdoor Design (ODD) program is based on the consigned drawings. According to a Chrysler's manager, 70% of Chrysler's manufacturing cost is procurement parts, and 40% are already black box parts as of 1993 (a presentation by Thomas T. Stallkamp, Vice President Procurement and Supply, General Manager Large Car Operations, Chrysler Corporation, on December 7, 1993 in the "1993 Global Automobile Conference", Management Centre Europe, Brussels, Belgium). According to him, though, whether the parts drawings are owned by Chrysler or by suppliers depends upon the types of parts. Further investigation is needed for this issue.

[3] See Mitsubishi Research Institute. (1987, p.7).

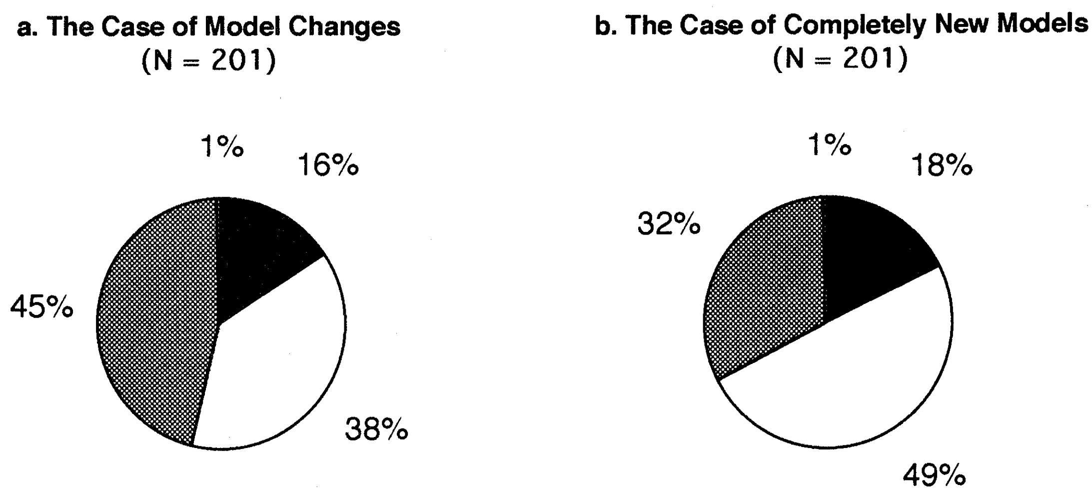
[4] See Mitsubishi Research Institute. (1987, p.11).

[5] For example, nearly ten suppliers of plastic resin competed to win contracts with Toyota for its new generation bumpers in the early 1990s. A supplier that had been rejected by Toyota in the previous generation got the first and the most lucrative contract, as it was the first company to meet the technical requirements set by Toyota.

[6] For further details of the survey, see section 2.3 of this paper.

[7] At Nissan, this type of drawings are simply called "parts drawings" (buhinzu).

Figure 3 Types of Competition among Japanese Parts Suppliers



Key:
- bidding based on detailed parts drawings provided by the car maker
- development competition among more than one parts suppliers based on specifications provided by the car maker
- selection of a particular parts supplier by the car maker at the stage of product concept, product planning or specification development
- others

Source: A Questionnaire survey by the author in 1993. Almost all of the respondents are first-tier suppliers belonging to Japan Auto Parts Industries Association.

and equipment, and lend them to suppliers. In this case, the suppliers are regarded as nothing more than providers of production capacity.

There are some other ways for the suppliers to get involved in new car development projects, including an arrangement called "guest engineer," or "resident engineer," in which component engineers are dispatched from the supplier to the car maker to work jointly with the latter's engineers.

Overall, each company or project chooses the degree of supplier involvement component by component, which in turn determines overall division of engineering work between the assembler and the suppliers. It is important to note here that the decision on manufacturing vertical integration and that on engineering vertical integration are two separate issues: for a given production in-house ratio, engineering in-house ratio could range widely. In any case, the decision on the mix of the parts types depends upon the company's strategy, nature of the component, as well as capabilities of suppliers and characteristics of supplier networks.

2.2 Current Practice: The Case of Toyota's Black Box Parts System

As we will discuss later, Toyota is the company that established the intra-company procedures on the black box parts system (approved drawings in particular) earliest in the industry. The current paper will therefore focus on Toyota' practice for the time being. Although the black box system is supported not only by formal procedures but also skills, attitudes and other factors of organizational cultures, the system of formal documents is an indispensable backbone of the system.

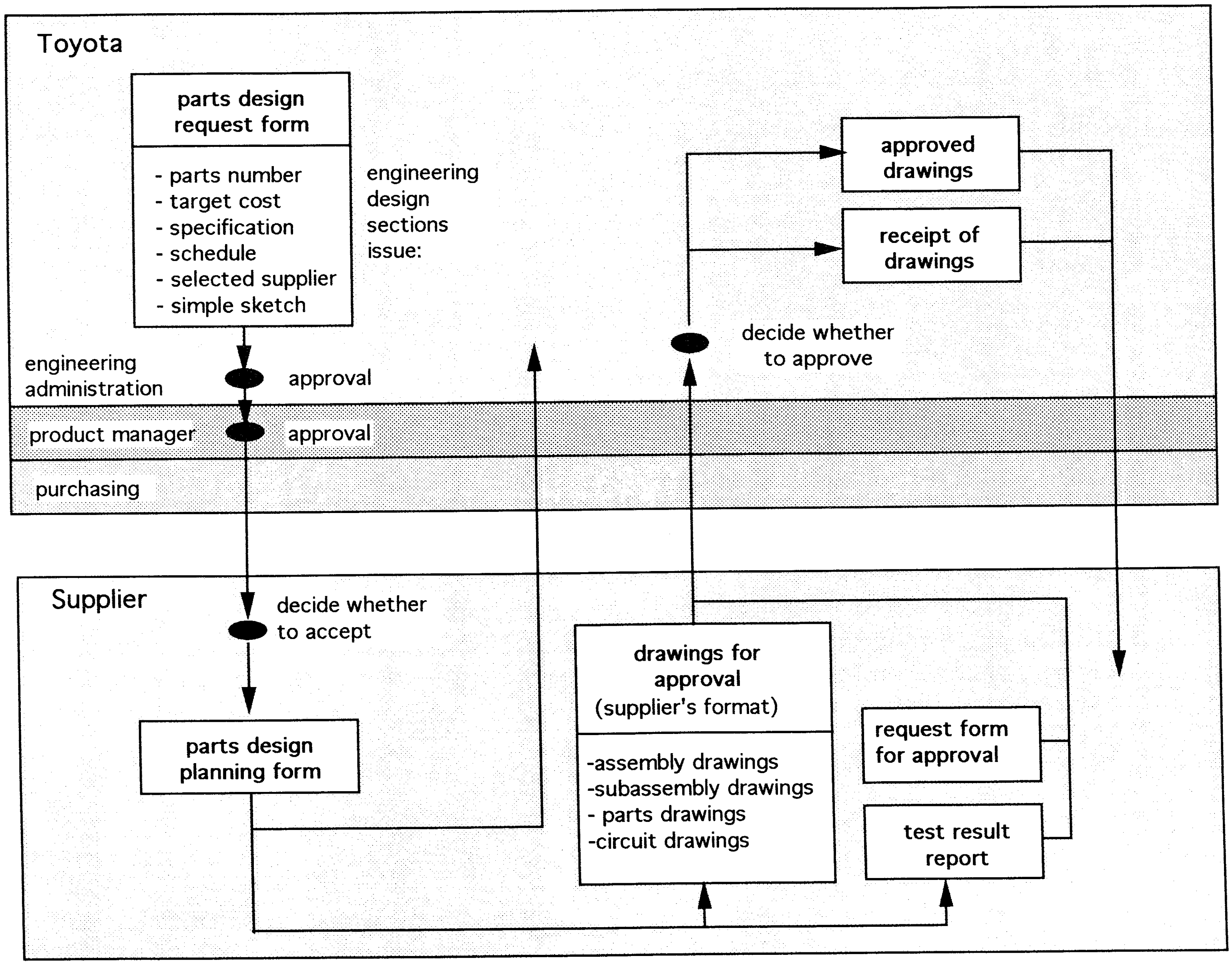
Figure 4 describes the current system of formal documents at Toyota (reconstructed from an interview at Toyota). First, "parts design request form" is issued by Toyota's product engineering design sections, which gets approvals of Product Managers (Chief Engineers) and Engineering Administration Department (sekkei kanribu). It is then released to the potential supplier through Purchasing Planning Department (kobai kikkakubu). After examining the request and deciding whether they accept Toyota's request, the supplier complete "parts design planning form" by adding necessary information to the design request form and send it back to Toyota.

The supplier then conduct detailed engineering, complete a set of drawings, make component prototypes and test them. The format of the drawings are based on each supplier's format, although it has to be approved by Toyota's Engineering Administration Department. The drawings for approval include assembly drawings (detailed), sub-assembly drawings, circuit drawings, critical parts drawings, and print circuit board drawings.

The supplier then send the package of the drawings, a request form for approval and a test result report back to Toyota in order to get the latter's approval. Toyota checks the documents to decide whether it approves the drawings. Once it gets the approval, the supplier owns the drawings and has to take full responsibility for quality assurance of the parts.

Toyota also established a formal system of shifting a particular component transaction from detail-controlled to black box parts system (or starting a new transaction with the black box arrangement) in the early 1990s. According to

Figure 4 Flow of Documents for Approved Drawing System at Toyota



this system, Toyota's product engineering sections can submit a request form for changing a transaction from the detail-controlled system to the black box parts system to Purchasing Department, which negotiates with the engineering section to coordinate engineering and cost requirements. If the Purchasing Department approves the change, the transaction is shifted to black box parts system. If not, product engineer still have a second chance to further discuss with purchasing people for future change. Although Purchasing Department is formally in charge of negotiation with the supplier for the shift, product engineers informally talk to the suppliers in advance, with a conversation such as "Are you ready for taking quality assurance responsibility? Becoming an approved drawing supplier is a kind of tough experience," "Yes, we are ready now."

The procedure also specifies criteria for the shift as follows:

(1) The shift to black box parts should not result in erosion of Toyota's technological potentials or leak of its basic know-how. Toyota should refrain from subcontracting engineering design just for saving in-house engineering resource.

(2) The shift should save engineering person-hours, which can be used elsewhere.

(3) The supplier should have capability of testing and evaluating the component as a unit based on Toyota's specification requirements.

(4) The shift should result in total cost advantage. That is, the cost saving in Toyota's engineering hours must be compared with increase in the parts cost.

(5) For certain parts. the suppliers should have capability to handle CAD (computer-aided design).

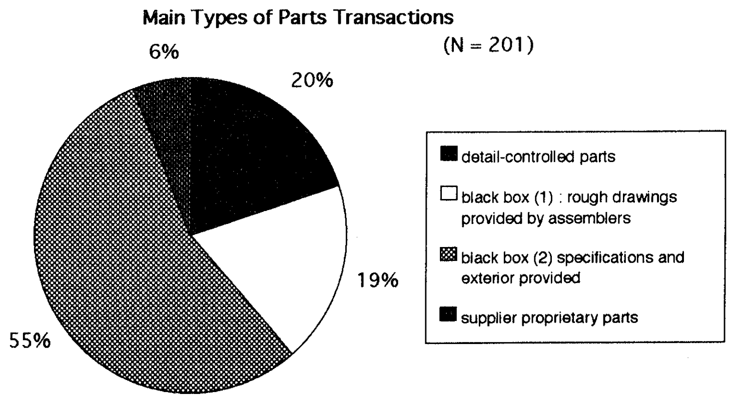
The above procedure indicates that Toyota is continually making decisions on whether to subcontract design engineering to parts suppliers by evaluating marginal cost and marginal benefits of the shift.

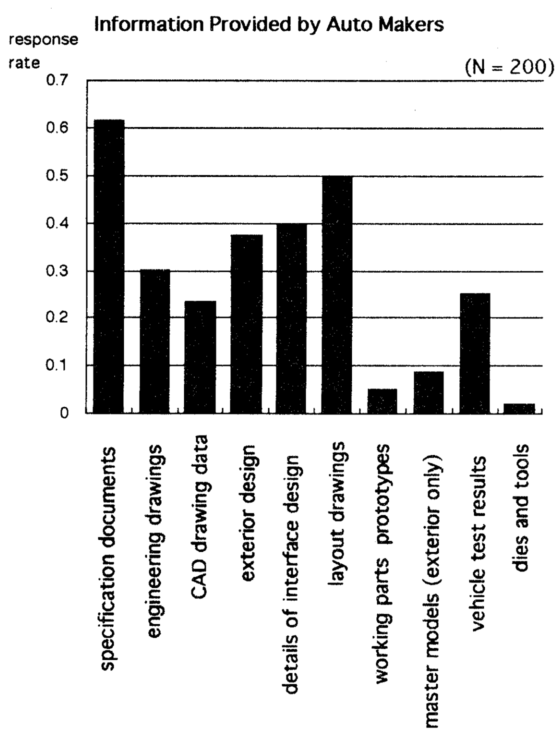
2.3 Current Practice: Results of the Supplier Survey

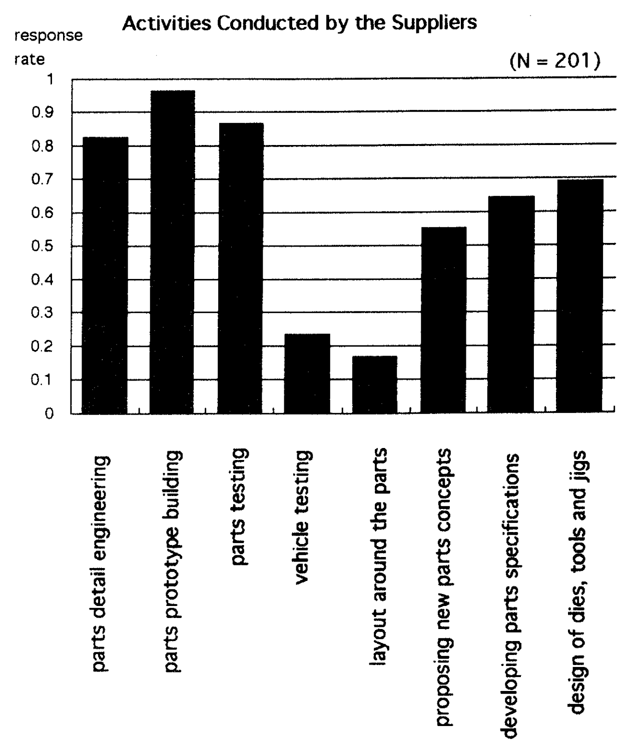
In order to further investigate current practices and historical origins of the black box parts system, the author made a mail survey for the member companies of Japan Auto Parts Industries Association (JAPIA), most of which are first-tier parts suppliers making direct transactions with the Japanese auto assemblers, in September and October 1993 [8]. Although details of the survey result will be presented elsewhere, figure 5 shows some of the results on the current practice of design activities by the Japanese first-tier auto parts suppliers. The results are generally consistent with the descriptions earlier in this paper: about three-fourths of the respondents answered that their main

[8] The questionnaire was mailed to 438 companies, of which 199 made valid responses (45% response rate). One company made three responses for three different product groups, so the total number of the sample is 201. Actual sample size differs depending upon the questions. On average, annual sales of the sample companies was 73 billion yen (201), the number of employees was about 1900 (201) (sample size in parenthesis). The author appreciates efforts and cooperation of Mr. Akito Ozeki (JAPIA), Mr. Ryuji Fukuda (The Japan Association for the Research on Automotive Affairs), and Ms. Keiko Shiroki (research assistant to the author).

Figure 5 Some Results of the Supplier Survey







Source: Questionnaire survey to the members of Japan Auto Parts Industries Association in 1993.

type of transaction was black-box parts system, with either specifications (55%) or rough drawings (19%) provided by the auto makers. Detail-controlled parts (20%) and supplier proprietary parts (6%) were both minorities. This result is also consistent with the one in Clark and Fujimoto (1991), although the method of measurement is not identical between he two (see the Japanese case in figure 6).

As for information inputs, specification documents, layout drawings, details of interface design, and exterior design were the inputs that the auto makers provided most frequently, which is also consistent with general description of black box parts system in Japan. Also, the most frequently conducted engineering activities among the sample firms included parts prototype building, parts testing, and parts detailed engineering, followed by tool designs, pats specifications, and parts concept proposals.

The survey also showed that average R&D spending per sales of the sample companies was 2.6% (185), and capital spending per sales was 6.1% (186) (sample size in parenthesis). They employed about 170 product engineering and 280 manufacturing engineers on average.

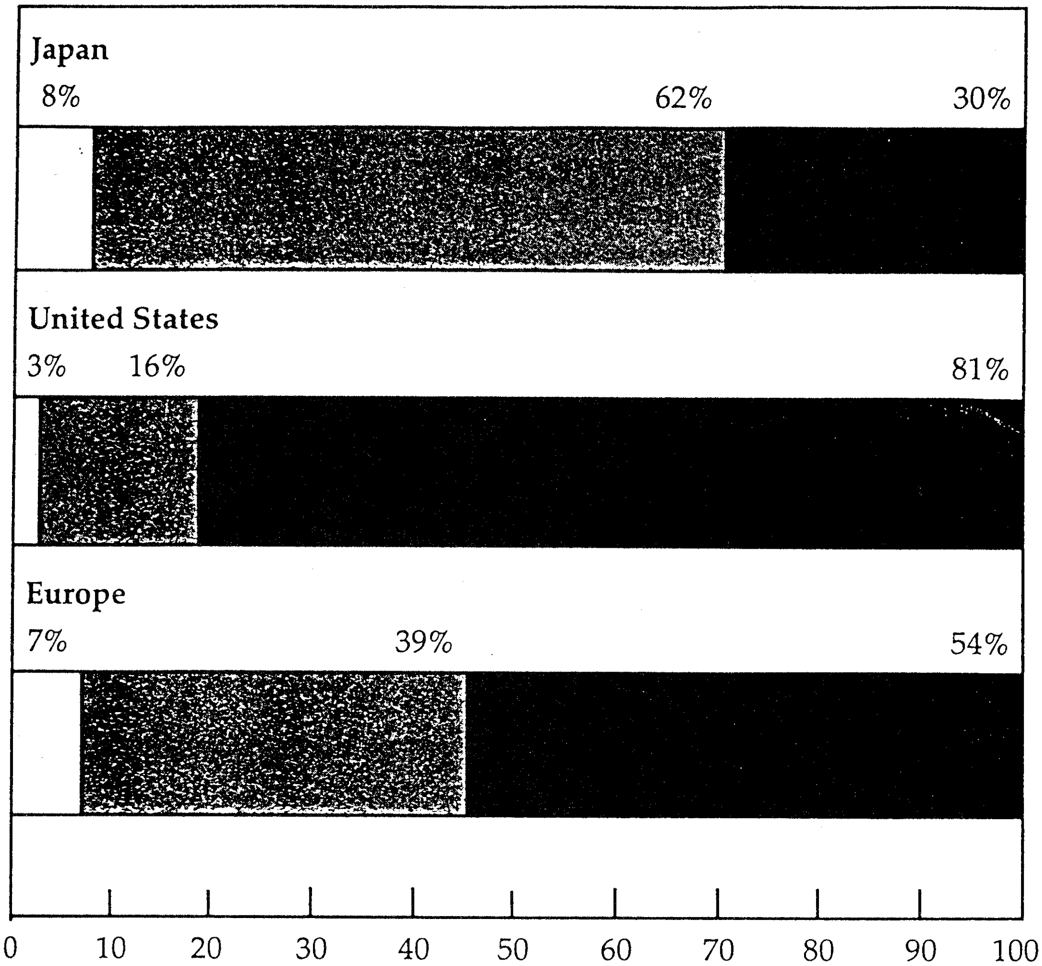
2.4 Literature Survey

Although there have been many studies on manufacturing practices and subcontracting systems of the Japanese auto industry, researches on product development side of the supplier system have been relatively scarce. One of the important exceptions has been a series of systematic studies by Asanuma (1984, 1989), which described and analyzed the inter-firm flow of design information between assemblers and suppliers. He defined various categories of suppliers, including approved drawing system, in terms of a combination of suppliers' relation specific skills and made some propositions that predicted how the level of relational quasi-rent differs among the categories (Asanuma, 1989). In this way, Asanuma gave a clear economic interpretation to the effectiveness and stability of the black box parts system. Asanuma also pointed out that the approved parts system may have originated from either marketed goods or from provided drawing parts in different ways, and that black box parts (approved drawings) are found more often in the Japanese automobile industry than in the electric machinery industry.

Nishiguchi (1989) thoroughly studied the practice of the Japanese style subcontracting system and described it as "strategic dualism", the new form of contractual relations which was based on "problem-solving-oriented collaborative manufacturing." He also argued that the system was the evolutionary product of a complex historical interaction. As a part of this system, Nishiguchi suggested that the black box design concept evolved from what he calls "bilateral design" of the late 1950s and early 1960s, in which suppliers made VA (value analysis) and VE (value engineering) proposals, as well as supplier-driven innovations, for the auto makers.

Fujimoto and Clark (1991), by collecting data from 29 product development projects from Europe, US and Japan in the late 1980s, found that the average Japanese project in our sample rely much more on the black box parts than the average American project, which heavily uses detail-controlled parts (figure 6). Europeans are positioned in the middle. Together with the

Figure 6 Types of Parts Procured by Suppliers



Note: Percentages shown represent fractions of total procurement cost.

Suppliers' Proprietary Parts

Black Box Parts

Detail-Controlled Parts

Source: Clark and Fujimoto (1991, p. 145) supplier proprietary parts, the average Japanese project of the 1980s relies on supplier's engineering in roughly 70% of purchased parts, as compared with 20% in the U.S. and 50% in Europe. Note that the average fraction of procurement cost in total production cost is about 70% in Japan, 70% in the U.S.(this includes parts from component divisions of each company), and 60% in Europe in the same sample[9]. They also estimated that lower in-house development ratio of the Japanese makers contributed to their lower engineering hours per project (i.e. higher development productivity).

In the second round survey conducted in 1993, the same authors found that the US car makers increased the ratio of black box parts significantly. This is considered to be a part of their catch-up efforts to narrow the competitive gaps against better Japanese makers.

Cusumano and Takeishi (1991) studied the parts suppliers of four different component categories, and found that the Japanese car makers relied more on black box parts system in the parts studied.

Takeishi, Sei and Fujimoto (1993), by collecting data from about 120 parts suppliers in Kanagawa prefecture, which included not only first tier but also second, third and fourth-tier parts suppliers, indicated that a majority of the first tier suppliers in the sample (59%) made either black-box or supplier's proprietary parts, while the fraction was much smaller (23%) in the second-tier suppliers and none in the third-fourth tier suppliers. This implies that black-box parts practice is concentrated heavily on the first-tier suppliers.

Thus, the current practice of black box parts has attracted much attentions of both practitioners and researchers in recent years, and there have already been several important works on this subject. However, there has been hardly any literature that explored historical aspects of the system. Besides, to the author's knowledge, there has been virtually no description on this topic in official company histories of major Japanese auto companies and parts suppliers. Against this background, the current paper will examine how the system evolved over time by relying mostly on first-hand data from the companies in question.

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[9]Regarding the component divisions as inside the companies, Mitsubishi Research Institute. (1987) estimates average U.S. outside parts ratio to be 52 to 55 %.

3. Hypotheses on the Emergence of the System

3.1 The Logic of System Emergence versus System Stability

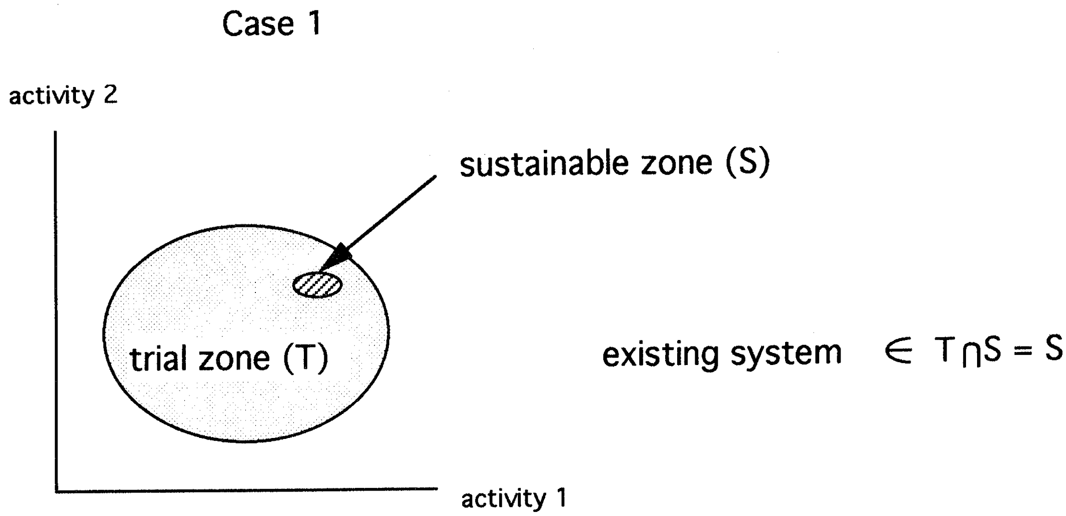
When we observe a certain stable pattern of organizational activities and capabilities in a group of firms, such the black box parts practice among the Japanese auto makers, there are at least two way of explaining the phenomenon: explanation on how the pattern emerged (the logic of system emergence), and that on how it was sustained (the logic of system stability). Although the they are intertwined in the real world, the two kinds of logic can be, in theory, discussed separately: What we observe now is the system that emerged and was sustained by now.

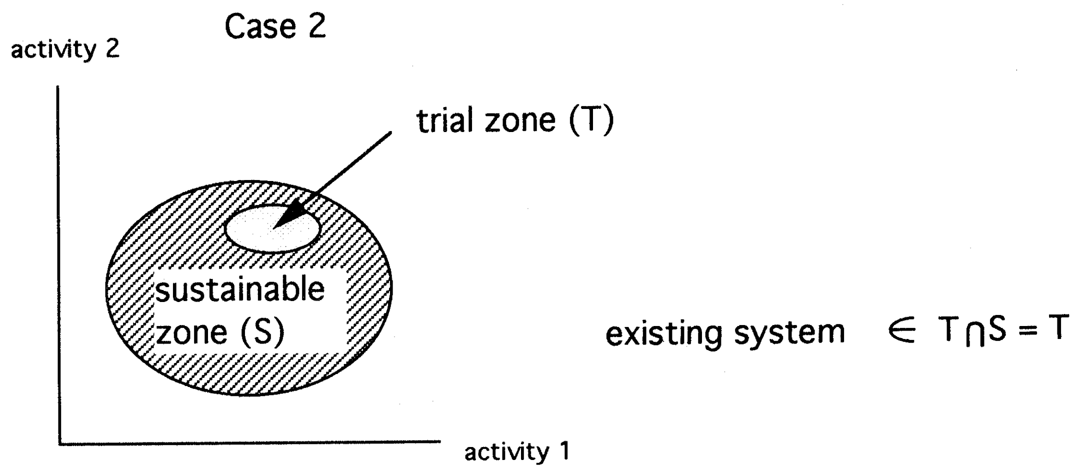
The standard economics, applied to the issue of institutional design, has focused on the logic of system stability by applying the notion of equilibrium in terms of sunk cost, transaction cost, game theoric strategy and so on. Other explanation of system stability includes "satisfycing" advocated by Simon (1945), as well as "stickiness" of social and organizational cultures. For example, an economist may explain that the black box parts system exists because it economizes transaction cost and creates quasi-rent based on relation-specific capabilities (see, for example, Aoki, 1988, and Asanuma, 1989). Others may argue that the practice can lower product development cost and/or manufacturing cost though the learning effect.

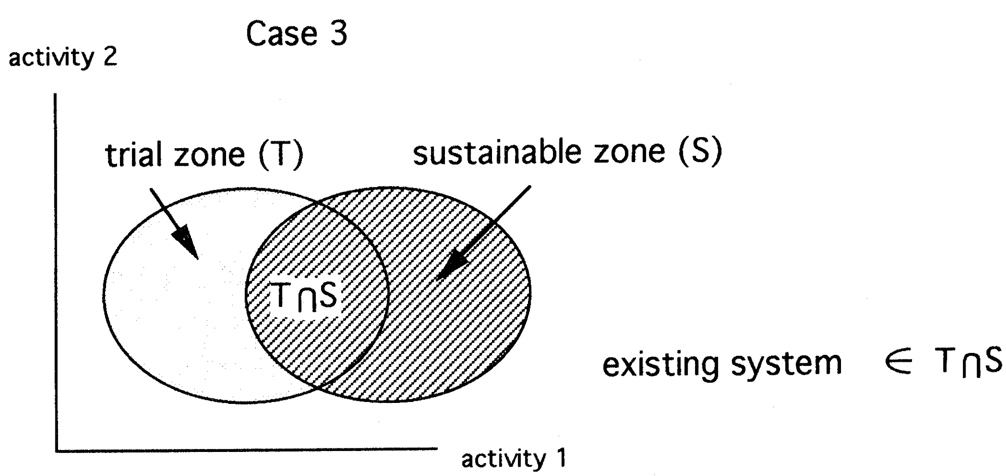
Let us now consider a situation where an economic actor tries to change its characteristics of the system (i.e. combination of its activities) according to a certain changes in environments, capabilities or goals. If the actor is allowed to make a wide range of trials for the change, and/or the range of the sustainable systems in the new situation is narrow, the logic of system stability would be enough to explain why we observe the system now. See case 1 of figure 7, for example, in which the zone of trials in the activity space totally contains the zone of sustainable systems. As what exists should be found in the product of the two areas, which is nothing but the sustainable zone itself, the explanation of system emergence does not give additional information to us. This is the case when the sustainable system is found only in an equilibrium point (a neoclassical situation), or when actors makes numerous trials for change as they are cost-free (a Darwinian situation). Also, when the system does not change in the long run, it is obvious that the logic of stability is sufficient to explain the phenomenon.

However, if the environment is generous enough to let a variety of system patterns survive, and if the opportunities for system changes are limited, then the logic of emergence add information on why we observe the pattern now. In figure 7 this is the situation where the trial zone does not contain the sustainable zone (cases 2 and 3). Our observation of the recent production system of the automobile industry seems to fit the latter situation: We have observed a wide variety of system performance and practices in existing auto makers, as well as their dynamic changes (Womack, Jones and Roos, 1990; Clark and Fujimoto, 1991). Thus, it seems that the logic of emergence provide useful information in explaining why we see certain practices, including the black box parts, in the current production system of the Japanese makers.

Figure 7 Cases Where Logic of System Emergence Matters







3.2 Generic Hypotheses of System Emergence

A study of the emergence of the system is essentially a historical analysis. It tries to explain why a certain economic organization chose a particular set of trials for system changes. Generally speaking, there are at least several alternative logic of explaining emergence of a new pattern as follows (figure 8).

- *Random trials:* This logic assumes that it is a matter of pure chance for an organization to choose a particular trial. A lucky one gets a better system, while an unlucky one gets a poor one.

- *Rational calculation:* An organization deliberately choose a new course of action that satisfies or maximizes its objective function by examining a feasible set of alternatives based on its understandings of environmental constraints and limits of capabilities. The neoclassical decisions further assume that the economic actors are equally capable and face the identical environment.

- *Environmental constraints:* An organization detects certain constraints imposed by *objective* or *perceived* environments, and voluntarily prohibit certain set of actions. The constraints may be objective (e.g. laws and regulations), or it may be a self restraints based on its perception of the environments. Obedience to other organizations is also included in this category.

- *Knowledge transfer:* A certain pattern is transferred from another organization to the one in question. The transfer may happen within the industry (competitor, supplier, customer, etc.) or across the industries. Also, the transfer may be a *pull* type, where the adopter-imitator of the system takes an initiative, or it may be a *push* type, where the driving force of the transfer exists on the side of the source organizations.

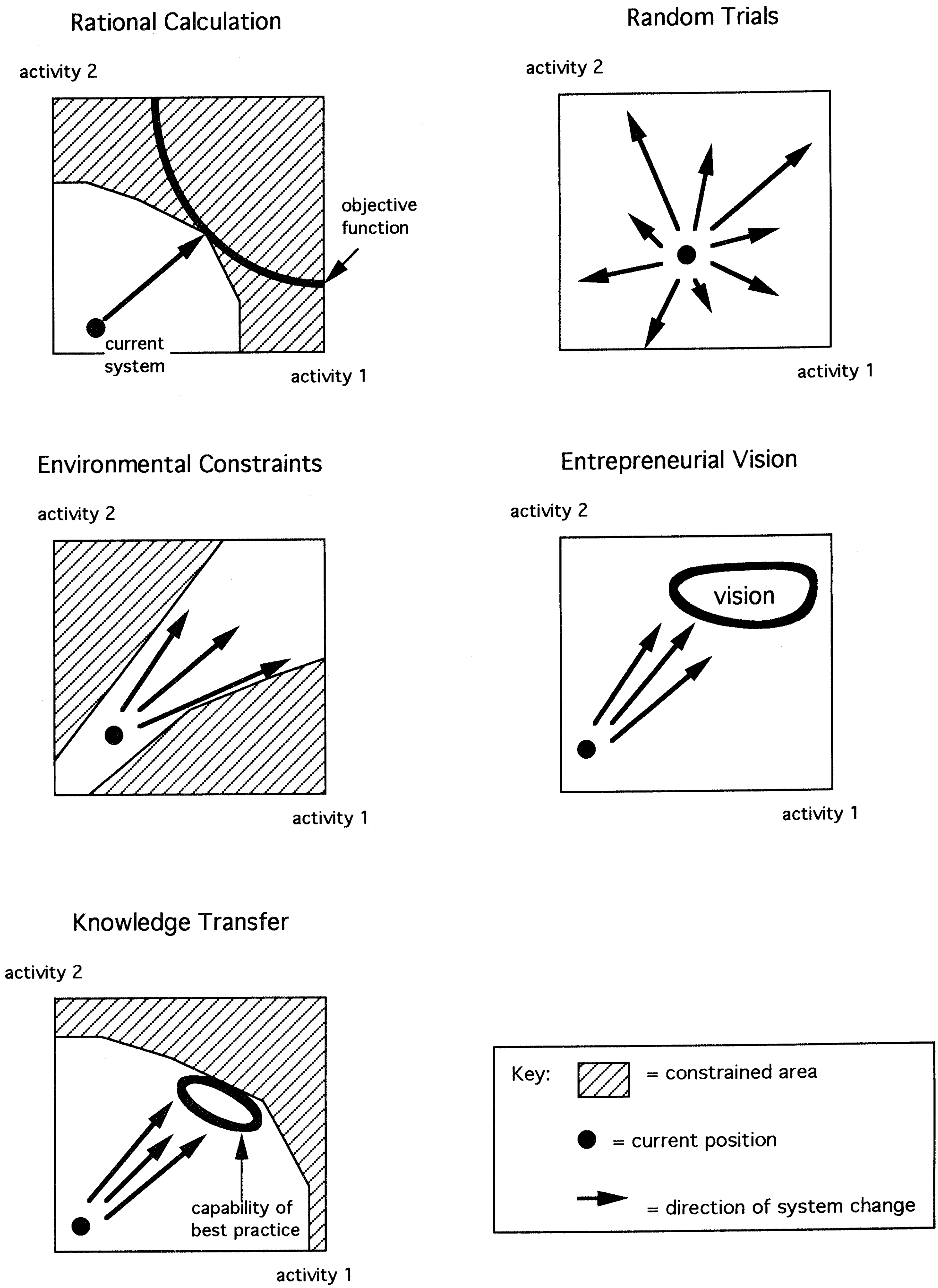
- *Entrepreneurial vision*: A desirable set of activities is directly chosen by entrepreneurs of the organizations based on their visions, philosophies or intuitions without much analysis of their capabilities and constraints.

This may not be an exhaustive list of possible logic of system emergence. Nor is it likely that we can explain a certain system evolution by a single logic. A combination of different logic would be normally needed.

3.3 Specific Hypotheses on Evolution of Black Box Parts

Let us now turn to the subject of the black box practice in the Japanese auto industry. Why did this system emerged? This question may include two sub-questions: How it started in the first place, and why it prevailed in the industry. Applying the generic framework discussed above, we can examine the following specific hypotheses. As a starting point, let us accept some "stylized facts" on this phenomenon: (1) Black box parts system is a post-war phenomenon; (2) The practice was gradually diffused to the Japanese suppliers; (3) One of the early adopter of the system was Toyota. Based on these assumptions, several hypotheses, as well as their preliminary evaluations, are presented as follows:

Figure 8 Some Generic Hypotheses of System Emergence



H1: *Because of cost-effectiveness analyses by the auto makers (rational calculation)* : Although this is a popular explanation after the fact, the cost effectiveness of the black-box parts practice is not that obvious. One may argue that the Japanese auto makers knew that long-term advantages of joint development would more than compensate for the short-term disadvantage due to early selection of suppliers. However, there are some evidences that the auto makers, particularly purchasing departments, emphasizing cost reduction through competitive pressure among the suppliers, tended to insist that they would lose negotiation power if they chose the black box suppliers too early. The hypotheses that the Japanese makers knew the long-term benefit of the system, while the Americans did not, may be plausible, but we should not rely too much on this type of "after the fact" explanation.

H2 *Because the auto makers did not have component technology in-house (environmental constraints):* This hypothesis assumes that the Japanese auto makers of early days did not have sufficient capability of component technologies and had to rely on design activities of the parts manufacturers. While it was true that the early auto assemblers in Japan tended to lack sufficient capability of component engineering, so did the early component manufacturers. Prior to the 1930s, automobile mass production did not exist in Japan: the domestic auto assemblers were little more than small volume prototype makers. Design drawings for mass production did not exist in the first place. Ford and GM then almost dominated the Japanese market in the late 1920s and early 1930s, but their assembly operations in Japan relied mostly on imported knock down parts. Finally, when the protectionist regulation of the 1936 ousted Ford and GM and helped start-up of Toyota and Nissan, these Japanese assemblers had hard time finding reliable parts suppliers in Japan. Toyota was almost forced to rely more, not less, on in-house engineering and manufacturing of its components. Thus, early history of the Japanese auto industry does not seem to support the hypothesis that lack of component engineering capabilities of the assemblers created the black box parts arrangements.

H3 *Because auto makers did not have sufficient amount of resources (environmental constraints):* The Japanese auto industry grew rapidly in terms of both production volume and the number of models between 1950s and 90s. Thus, there is a possibility that the Japanese car makers could not expand their production and engineering capacities rapidly enough to match the pace of the market growth. One of the ways to respond to this "forced growth" problem might have been to subcontract out a significant portion of both production and engineering activities to the suppliers. I other words, this hypothesis simply says that the car makers created the black-box parts system because they were too busy to handle all of the rapidly expanding workload. While this hypothesis may explain why the black box parts system prevailed in the high growth era, it may not explain why the system was initiated before the high growth started, as discussed later.

H4 *Because the practice already existed in other industries (knowledge transfer):* Another possibility is that the practice of black box parts already existed in other industries, from which the automobile industry adopted the system. Some other machinery industries, such as ship building, locomotives and aircraft, have to be examined in this regard[10]. However, so far we have not found any clear evidence that the concept of black box parts was transferred from such industries.

H5 *Because the practice already existed in other firms in the industry (knowledge transfer):* Since the early auto makers, including Toyota and Nissan before the war, adopted many of the elements of Ford and GM production systems, one may wonder if this was the case with the black box parts (Fujimoto and Tidd, 1993). However, GM and Ford, while they were making motor vehicles in Japan during the 1920s and 30s, did not use the black box practice: their operations were essentially KD assembly. Back in America, black box parts was not a prevalent practice, either. In America, the cars prior to the mass-production era relied much on marketed goods (suppliers proprietary parts), while the mass producers tended to rely on detail-controlled parts. (Abernathy and Clark, 1983) Thus, it is not likely that the black box parts system was originally imported from the Western auto makers.

However, the transfer mechanism inside Japan will, of course, explain why the system prevailed rapidly among the Japanese auto makers and suppliers. That is, the diffusion of the black box parts may have been caused either by direct or indirect transfer of knowledge between auto makers, between parts suppliers, from assemblers to suppliers, or from suppliers to assemblers.

H6 *Because of the visions of the founders/entrepreneurs (entrepreneurial vision)* : Kiichiro Toyoda, the de facto founder-entrepreneur of Toyota Motor Corporation, deserves special attention. It is known that Kiichiro Toyoda made many visionary statements in the early era of Toyota[11]. Some of the visions were unrealistic in the short run (e.g. catching up with the US makers in productivity within three years after 1945), but many of them may still have long-term impact on Toyota's corporate culture. The question is, whether Kiichiro had entrepreneurial intuition in the area of supplier management.

H7 *Because of a pure chance (random trials)* : Any historical evolution of a new system is likely to be influenced at least partly by pure chances. The case of black box parts does not seem to be an exception. From a researcher's point of view, though, explanation of a system emergence by a sequence of chance events should be the last, not first, thing to do. In other words, while the author does not deny the impact of pure chance, the paper will try not to explicitly ascribe the emergence to them.

Thus, the foregoing preliminary analyses of each of the specific hypotheses indicate that the Hypotheses 2 (growth with resource constraints), 3 (technological constraints), 5 (intra-industrial transfer) and 6 (entrepreneurial visions of Toyota's founders) may deserve further investigation. Also, it

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[10] In the prewar aircraft industry, the Japanese military authority gave specifications to potential aircraft makers, ordered to make prototypes, and selected aircraft suppliers based on evaluation of the prototypes (See, for example, Maema, 1993). There is no clear evidence that such a practice influenced purchasing system of the early automobile industry in Japan.

[11] See, for example, Fujimoto and Tidd (1993).

seems to be important to note that the origin and diffusion of the system may be separate in logic and timing from each other, and thus they need separate explanations. Based upon the above preliminary predictions, the subsequent sections of the paper will explore these hypotheses more in detail. The section 4 will focus on the origin of the practice, while sections 5 and 6 will shift attention to diffusion of the system within and across the firms.

4 Origin of Black Box Parts System

4.1 Toyota in the Prewar Era: In-house Parts Production

Let us start with the origin of the black box parts system. Historically, there are only two Japanese auto companies that has possibility to have initiated the black box parts practice on mass-production basis: Toyota and Nissan. The two companies, established in the 1930s after Ford and GM were virtually ousted from Japan by the protectionistic law of 1936 (Automobile Manufacturing Enterprise Law), were obviously the first large scale automobile manufacturers in Japan. Between the two companies, however, there are some historical evidences (discussed later in this paper) that indicate that Toyota introduced the black box parts in a more systematic manner, if not earlier, than Nissan. For this reason, the present paper will focus mainly on the early history of Toyota.

Toyota's automobile production, led by founder-entrepreneur Kiichiro Toyoda, began in the early 1930s. After getting top management approval of starting Automobile Division in Toyoda Automatic Loom, Kiichiro and his staff ordered machine tools for prototype building from Germany and the U.S., purchased a Chevrolet car, reverse-engineered it, sketched the decomposed parts, and estimated materials used. They then started making prototypes by using idle time of the loom production line, while selecting a site for a new automobile plant.

After visiting some imitation parts makers in Tokyo and Osaka, they found that parts quality of those potential suppliers were quite low, and that Toyoda would have to make most of the parts in-house at the initial stage, and to rely heavily on parts designs by Ford and GM. Thus, Toyoda decided to design the first prototype by combining designs of the Chevrolet engine that had been regarded as fuel efficient and the Ford chassis that was robust enough for Japan's bumpy roads. When Kariya plant started in 1936, Toyoda could not obtain appropriate sheet steel from Japanese makers and had to import it from Armco of the U.S. Electric parts occupied the largest fraction of the imported parts, which made Toyoda to make them in-house[12]. They were based on sketches of American parts that were reverse-engineered, though.

Thus, it was difficult for Toyoda to purchase appropriate parts and materials from domestic suppliers at its initial stage of automobile production. Despite this difficulty, 55% of unit manufacturing cost was that of parts purchased from outside companies in 1936; Only 12% was imported parts, while the rest (43%) was from domestic source.

Toyota Motor Manufacturing was established as an independent company in 1937. In 1939, after the world war II started in Europe, Toyota changed its

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[12] Toyota Jidosha 20 nenshi (20 Year History of Toyota Motor Manufacturing), p. 108.

management policy for expansion of production. As a part of the new policy, Toyota emphasized in-house production of parts. The number of purchased parts per vehicle (excluding bolts and nuts) was about 700 in 1939. The number was reduced to 570 (about 3000 yen per vehicle) by 1940, when a new target, 380 items (1000 yen per vehicle), was set[13].

In the long run, however, Kiichiro Toyoda had a vision to grow a group of component specialist companies outside Toyota. In the case of electric parts, for example, Toyota had to make the parts in-house at its Kariya plant, but Kiichiro was writing in his 1940 memo that he would separate out electric parts production to specialist companies as soon as production volume expands[14]. Thus, although Toyota had to emphasize in-house production for the time being, Kiichiro had a long-term vision to create specialist parts vendors.

4.2 Prewar Categories of Toyota Suppliers

In the 1940 order to switch to in-house parts production, Toyota classified purchased parts into three categories[15]:

(a) Ordinary outsourcing (ippan gaichu): Made by general-purpose equipment. Toyota can therefore switch suppliers when necessary. Inspection of in-coming parts is necessary.

(b) Special outsourcing (tokushu gaichu): Needs certain equipment and technical assistance from Toyota. Close capital or financial ties with Toyota. Toyota has to let the suppliers make development prototypes as much as possible. Inspection is conducted at suppliers' premise.

(c) Specialist factory outsourcing (senmon kojo gaichu): Special kinds of parts that needs special-purpose equipment. Close capital and financial ties is needed in future. Inspection is conducted at suppliers' premise.

It is obvious that category (a) resembles the Western style supplier contracts with supplier switching and inspection. Categories (b) and (c), however, pursued long-term contracts and close capital or financial ties. Toyota needed long-term relations with the suppliers of these categories apparently because they needed technical assistance in manufacturing, and because such suppliers used transaction-specific equipment. Toyota also expected the category (b) suppliers to have prototyping capability. However, there was no descriptions on suppliers' design capability. Overall, Toyota already had intention to establish long-term ties with a group of suppliers, but this was mainly because of transaction-specific equipment and know-how in manufacturing. Design capability of the suppliers was not explicitly considered as sources of long-term supplier relations during the prewar era[16].

4.3 The Change in Procurement Policy at Toyota after the War

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[13] Toyota Jidosha 30 nenshi (30 Year History of Toyota), Toyota Motor Corporation, 1967, p. 172-182.

[14] Toyota Jidosha 30 nenshi, p277.

[15] Toyota Jidosha 30 nenshi, P. 182.

[16] In 1943, Toyota's supplier organization, Kyoho-kai, was established. Actual controls and assistance from Toyota to the suppliers was not significant at that time, though.

Soon after the World War II ended, Toyota changed its procurement policy again, emphasizing outsourcing this time. Kiichiro mentioned in his booklet:

> I want to change the parts manufacturing policy drastically. In the past, for various reasons, Toyota made many parts in-house and thus could not concentrate on parts procurement. From now on, we would grow specialization of our suppliers, have them do research in their specialty, and nurture their capability as specialist factories. We will ask such specialist manufacturers to make our specialist parts[17].

Although there are some evidences that Kiichiro already had this vision of creating a group of specialist vendors in the prewar era, it was after the war that Kiichiro declared this as a official policy.

4.4 The Birth of Nippondenso (1949)

In 1949, Nippondenso was separated from Toyota and became an independent company based on Toyota's restoration plan (saiken seibi keikaku) submitted to the government. The electric parts factory of Toyota was suffering from deficit[18].

The new company, Nippondenso, had design and engineering capability from the beginning: Virtually all of Toyota's electric component engineers, who were making parts drawings based on sketches of parts in the US cars (e.g. Delco and Lucas), were transferred to the new company to form Engineering Department there[19]. It naturally followed that the transactions between Toyota and Nippondenso were based on black box parts system from the beginning. Engineers of Nippondenso made its parts drawings based upon specification drawings (rough assembly drawings) provided by Toyota, which gave approval of the former's drawings. In other words, approved parts (shoninzu) system has existed at Nippondenso since 1949[20]. In 1951 a post was created to handle approved drawings as the number of such drawings increased. In 1952, Nippondenso expanded transactions with non-Toyota makers such as Mazda (Toyo Kogyo), Mitsubishi and Honda, which virtually meant diffusion of the black box practices outside the Toyota group.

In 1953, Nippondenso made a big decision on the choice of its technological base: it made a technical tie-up with Bosch of Germany to switch virtually all the parts drawings to those by Bosch under a license agreement. Initially, Nippondenso copied the Bosch drawings, which was then modified according to the customers' specifications. Production of Bosch-based parts started around 1955. In 1956, formal rules for handling approved drawings was established. The drawings with direct Bosch influence remained until the late 1960s.

4.5 Origin of Toyota's Procedures on Approved Drawing

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[17] Toyota Jidosha 30 nenshi, p 253 - 254.

[18] 30 Year History of Toyota (p. 277) hints that Kiichiro Toyoda had had a plan to grow separate electric parts specialists, while 20 Year History of Toyota (p. 300) indicates that the electric parts unit of Toyota was losing money, which was separated for better management. Which is the major motivation of the separation is not clear.

[19] This paragraph is based on an interviews with Yoshihiko Furuya, Director, and Michihiro Ohashi, General Manager, of Nippondenso on September 16, 1993.

[20] This fact was confirmed by Kazuyoshi Yamada, former engineer of Nippondenso.

Assuming that Toyota is the first mass-producing auto maker that systematically used the black box parts system, it is necessary to identify the time when Toyota formally started this practice. According to a survey of Toyota's purchasing and engineering procedures, the oldest document available, which uses the word "approved drawings" at Toyota is Approved Drawings Rule (shoninzu kitei) and Approved Drawings Handling Rule (shoninzu shori kitei) in 1953[21]. These internal rules of design office, in turn, mentions that they replaced similar rules of 1949. The 1949 documents themselves no longer exist at Toyota, according to our survey. It is not clear whether the internal rules existed prior to 1949, but given the fact that systematic formats for Toyota's documents were established in 1948, it is likely that the 1949 rule was the first formal rule that defined the approved drawings[22].

The coincidence in timing makes us suspect that the separation of Nippondenso from Toyota (also in 1949) might have been closely related to the origin of the black box parts (approved drawings) system. It is not clear if this separation itself made Toyota establish the black box parts rule, though[23].

In any case, Toyota's approved parts rule back in 1953 was rather simple: only one page and several sentences. The rule specified that the approved drawings be submitted to Toyota's engineering department via purchasing department, that engineering department processes the drawings according to the Approved Drawings Handling Rule, and that approved drawings be sent back to the supplier via purchasing department. The rule is has been essentially unchanged since then.

4.6 Possibility of Knowledge Transfer in the Pre-war Era

Although the transaction between Toyota and Nippondenso is likely to be an origin of Toyota-style approved drawing system, it does not necessarily mean that it was the origin at the level of the Japanese auto industry in general. In fact, according to the survey that the author conducted in 1993 (see section 5.6 later in this paper), six of the sample firms (i.e., 3% of the 177 respondents) answered that they had established the approved drawing system in the prewar era (before 1945). The six companies were three Nissan group suppliers and three independent parts makers (i.e., supplying parts to both Toyota and Nissan).

Looking at these early adopters of approved drawing system more closely, one may raise a hypothesis that the approved drawing system was in fact imported from other industries such as the prewar locomotive and/or aircraft. In fact, three of the above six companies had close connection with either of the industries: a brake parts maker (established in the early 1920s; initially making locomotive brakes under a license from an American manufacturer), a piston parts maker (established in the early 1930s; making piston parts for

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21 The descriptions of this paragraph is based on an interview with Toshihito Kondo, Masami Komatsu and Shoji Kasama, Purchasing Planning Department of Toyota, August 4, 1993.

22 For the unification Toyota's document format, see Toyota Jidosha 20 nenshi, p. 253 - 254.

23 Another possibility is that Toyota Auto Body, separated from Toyota in 1945, built cabs for Toyota based on the approved drawings. The appendix of 1953 approved drawings rule specifies how to handle the cabs by Toyota Auto Body as an exceptional case, though. This makes us suspect that the case of approved drawings by Toyota Auto Body did not become an issue prior to 1953.

aircraft, automobiles, ships, etc.) , and a shock absorber maker (established in the late 1930s as a subsidiary company of a locomotive parts supplier). The other two were suppliers of rather generic parts (textile and oil seal respectively), so they were probably "supplier proprietary parts" maker rather than black box parts maker[24]. Also, according to the same survey, early adopters of the approved parts system in the post-war era (1946 to 1955; 18 companies) included companies closely related to the prewar aircraft industry, such as two bearing makers, a shock absorber maker, a magneto maker, a carburetor maker, and a former aircraft fuselage maker. Many of the other companies supplied relatively generic parts (i.e. merchandise goods) such as tires, paint, oil filters, cables, and gaskets.

Thus, it is possible that the black box practice was transferred from the locomotive and aircraft industries, which were more advanced than the auto industry[25]. For example, Sawai (1985) argues that some locomotive and component suppliers accumulated technological capabilities and started joint engineering with the customer, the Ministry of Railroad, during the 1920s. The aircraft industry might have started the black box parts practice later (1930s), but its influence to the post-war auto industry might have been more direct. As some of major aircraft parts suppliers were located in the eastern part of Japan, Nissan, located mostly in the same area, might have learned this practice more directly than Toyota at this initial stage.

The above survey result also indicate the possibility that there is another path to the black box parts system: suppliers of relatively generic parts (e.g., tires, paint, etc.), or supplier proprietary parts, converted themselves to the black box suppliers[26].

In summary, it would be safe to say that Nippondenso was one of the very early adopter of the approved drawing system, but it was not "the earliest" one. It is nevertheless important to note that the Toyota's approved parts system turned out to be significantly more systematic and effective than that of the other auto makers including Nissan (see section 5.5). Thus, the Toyota-Nippondenso transactions might not have been the earliest of the black box practice in general, but it is likely to be one of the origin of the relatively effective version of the system (i.e., Toyota-style black box parts).

To sum up, the historical imperative (i.e. environmental constraints) in terms of technological capabilities, caused by the separation of Nippondenso, seems to be a main logic explaining the Toyota-style black box parts system. As for the approved drawings in general, transfer of knowledge from other prewar industries such as locomotives and aircraft may be important. In any case, it should be noted that, unlike many other elements of the automobile production systems, this was not a practice that was adopted directly or indirectly from the Ford system[27].

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24 One of the respondents were established after the war, so its response was excluded from the analysis.

25 The author appreciates some insightful suggestions from Haruhito Takeda and Kazuo Wada of Tokyo University on this issue.

26 This path was already predicted buy Asanuma (1989).

27 For the elements of the Toyota-style production systems adopted originally from Ford system, see, for example, Fujimoto and Tidd (1993).

5. Diffusion of Black Box Parts System

5.1 Post-War Development of the Japanese Supplier System

Let us now turn to the diffusion aspect of the system evolution. Before discussing the issue, though, we need to take a brief look at the background in and after the 1950s.

In the early 1950s, the Japanese automobile supplier system was very different from what we see today. Many of the basic patterns of so called Japanese supplier system, including long-terms relations, multi-layer hierarchies, "Alps" structure, Just-in-Time delivery, subassembly of components by first-ties suppliers, involvement of first tier suppliers in product development, competition by long-term capabilities, close operational control and assistance by the auto makers, etc., were gradually formed in the 1950s to 1970s. The high growth of production volume and proliferation of models during the 1960s facilitated the formation of multi-layer hierarchy of control and assistance.

According to Wada (1991), for example, a management diagnosis for Toyota and its twenty one suppliers (keiretsu shindan), conducted by staff of Aichi prefecture in the early 1950s, pointed out that Toyota had not provided enough technical supports to its Keiretsu suppliers, and that its purchasing department needed more people. Toyota quickly responded to this diagnosis and strengthened its technical assistance, inspection and data collection for its suppliers. On the supplier side, Kyoryoku-kai started to hold a series of joint seminars and plant visits. By the mid 1960s, activities of Kyoho-kai had been coordinated with Toyota's annual management objectives, and Kanban had been introduced to some of the suppliers.

Thus, by the end of 1970s, most of what we see today as the Japanese supplier system had been installed. The question is, whether the black box parts system followed this pattern.

5.2 Toyota and Nissan in 1960s: Model Proliferation

Triggered by the "motorization" in the domestic market, both production volume and the number of models increased rapidly in the 1960s. Roughly speaking, production volume expanded from 0.5 million units in 1960 to 2 million in 1965, and 5 million in 1970, mostly by expansion of domestic demand. Production volume continued to expand in the 1970s by rapid increase of exports and reached about 11 million units in 1980.

If the Japanese auto companies could not recruit sufficient engineers and workers to deal with the rapid expansion of production, it would be reasonable to predict that pressures to subcontract out a larger fraction of their operational tasks to the parts suppliers increased during the 1960s. In fact, literature on Japanese subcontracting system generally points out that it was during the 1960s that the auto makers started to purchase subassembly components, rather than piece parts, from their first-tier suppliers, and that they emphasized "specialist" parts suppliers[28]. Thus, it would be reasonable to infer that the Japanese auto makers actually subcontracted out a larger

[28] See, for example, Sei, Omori and Nakajima (1975), and Kikuchi (1976).

fraction of the production tasks to the suppliers under the pressure to grow rapidly with a constraint of in-house production resources.

A similar logic may hold in the case of product development and black box parts, although the pattern of model proliferation may have been somewhat different from that of production volume expansion. The number of basic models in 1960 (excluding foreign models produced by license agreements) was 8 in 1960 (2 from Toyota), 24 in 1965 (4 from Toyota), and 37 in 1970 (8 from Toyota), and 46 in 1980 (10 from Toyota)[29]. Thus, proliferation of basic models happened mostly in the 1960s (the latter half in particular), but it slowed down in the 1970s.

Figure 9 shows a rough estimate of the product development workload for Toyota and its suppliers since the 1960s, which shows that there were a few waves of development workloads: the late 1960s (Japan's motorization period) , around 1980 (between the two oil crises), and the late 1980s (the bubble era)[30]. Although the result is very preliminary, the figure seems to indicate that there may have been a significant pressures for Toyota and other major Japanese auto makers to alleviate the problem of growing development workload by asking the parts suppliers to do a part of the product development tasks.

In the area of product development, there has been almost no literature that pointed out that black box parts system (i.e. subcontracting of engineering tasks) was diffused rapidly during the 1960s. However, the author's survey conducted in 1993 clearly shows that the late 1960s was, in fact, the peak period of the adoption of the approved drawing system among the Japanese first tier suppliers (see section 5.6 of this paper).

An Interview by the author at Nissan also indicate that the black box parts system prevailed during the late 1960s at this company[31]. The diffusion process is said to have been quite informal, though. When an informal process of diffusion of black box parts system was going on at Nissan, Toyota was already refining its formal system for the system. In 1961, the internal rule on approved parts became a company-wide rule (sekkei kenkyu kitei) of seven pages. By the late 1970s, the rule had evolved into a very detailed procedure of nearly fifty pages. As discussed later, Nissan lagged behind Toyota in formalizing and systematizing the black box parts practice (section 5.5).

<u>5.3 A Case of Company A (1972 - 1992)</u>

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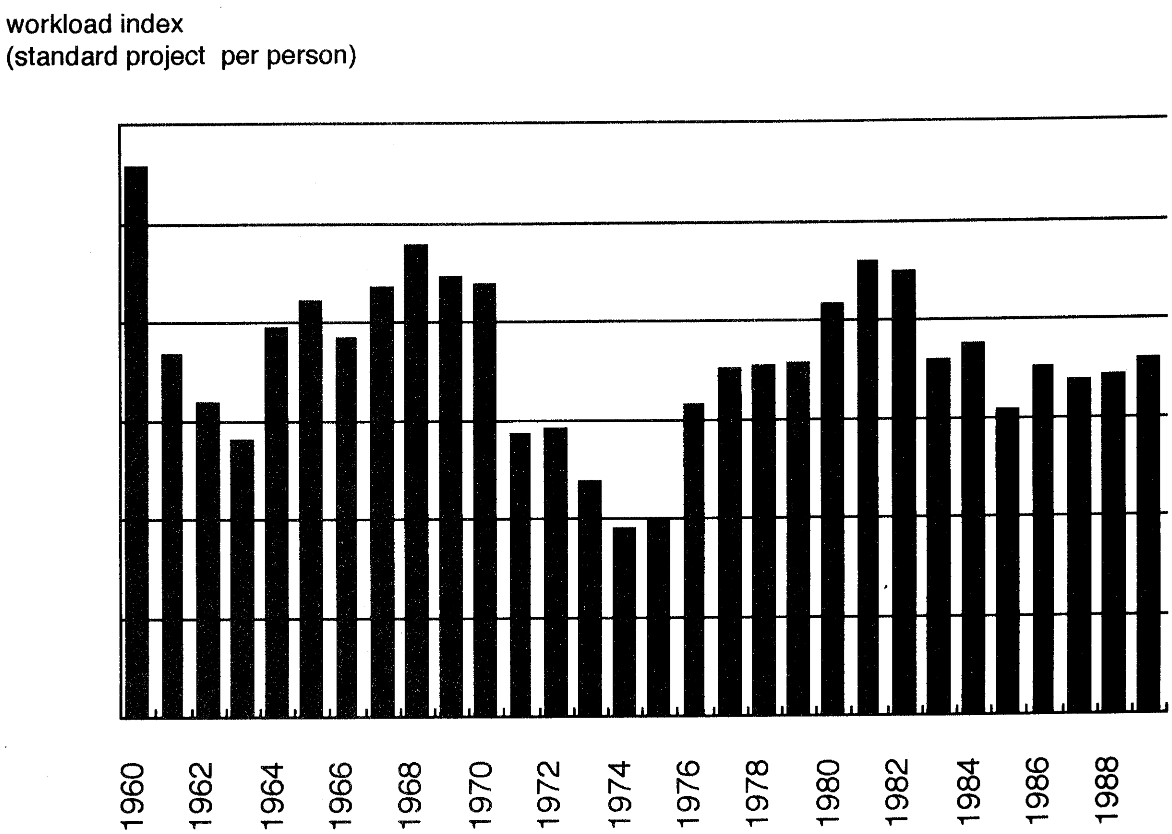
29 Clark and Fujimoto. "Product Development and Competitiveness." Journal of the Japanese and International Economy, 6, 1992.

30 The development workload was estimated by using a model change history table of Toyota that the author made and converting this into work load estimation by using a certain coefficients. It was assumed that the development lead time was 4 years, that the model was introduced at the end of the year, and that the development workload was 0.3 in the year of full model change or new model introduction, 0.3 in the previous two years, and 0.1 three years prior to the model change. The work load index was calculated by simply adding up the estimated work load of all models and divide it by estimated number of engineers at Toyota for each year. Thus, it should be noted that this is a very rough estimate of the time-series patterns of total development workload for the company. The estimation of the number of Toyota's engineers was made by using various sources, including Yano (ed., 1985) and Nomura (1993).

31 An interview with Ryo Hatano, General Manager of Material Purchasing Department, Nissan (May 8, 1993).

Figure 9 Estimated Workload of Toyota's Car Development



The data of Company A, a supplier of interior and other plastic parts, provide an intriguing case of diffusion of the black box parts within a supplier, as the company has supplied a wide variety of parts. The data shows how the company accumulated design capability in the past 20 years[32]. As figure 10 indicates, the company increased the number of parts drawings based on either approved drawings (shoninzu) or consigned drawings (itakuzu) almost quadrupled between 1972 and 1992. The share of black box parts in total number of drawings grew from 24% to 55% in twenty years. An interesting observation is that the fraction of consigned drawings increased very rapidly during the 1980s. This seems to coincide with the period when product variations (particularly those of the interior) proliferated due partly to the bubble economy. Considering a comment by a former executive of Company A, that the main motivation of car makers to adopt consigned drawings is shortage of their in-house engineers, the rapid expansion of this category in the 1980s is likely to be caused by the increased work load that was imposed on the car makers by the proliferation of product variations.

Breaking down the data by items provides even more intriguing facts: The patterns of design capability building differ widely across the types of the components (figure 11). In the case of functional parts, such as steering wheels and anti-vibration rubber, approved drawings increased. It is essentially because their functional targets can be unequivocally defined, and responsibility for quality assurance can be assigned. In the case of weather strips (rubber bands connecting glasses and bodies), consigned drawings has become a dominant mode, partly because responsibility for quality assurance is difficult to assign between the car maker (body), glass supplier and weather strip supplier. Detail-controlled system (provided drawings) still occupies a majority in interior parts, apparently because such parts are integrated with car makers' total vehicle (interior) design.

To sum up, types of parts transactions may differ depending upon characteristics of parts: When the parts are inseparable from total vehicle design (e.g. body stamping parts), they tend to be detail-controlled parts; When the parts can be functionally defined independently from total vehicle design, they tend to be approved drawing parts (or suppliers' proprietary parts in an extreme case); When responsibility for the parts' functions cannot be clearly assigned between the car maker and the supplier, consigned drawings tend to be more likely to be chosen.

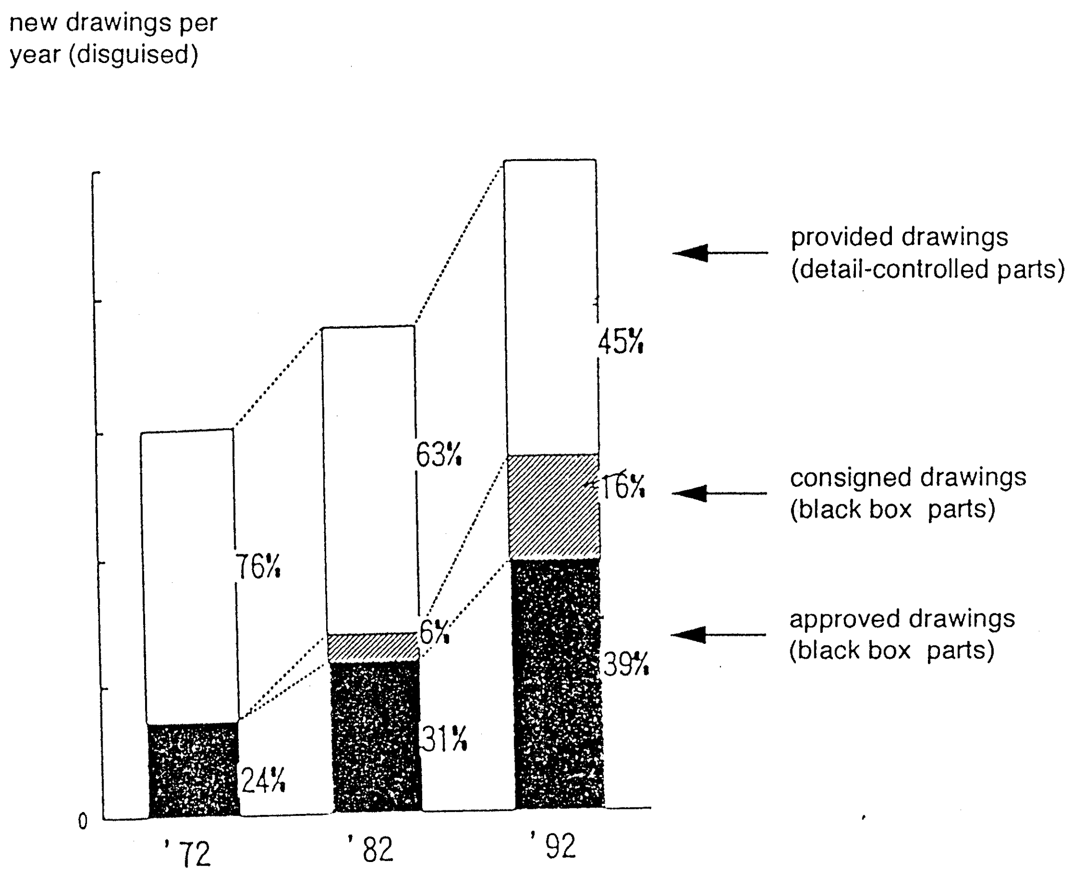
5.4 Toyota in 1980s: Continued Diffusion of the Black Box Practice

Diffusion of "approved drawings" continued at Toyota during the 1980s. According to a company data, the fraction of approved drawings in total number of engineering drawings increased from 30% in 1980 to 37% in 1992 in the case of Mark II model[33]. Proliferation of product variations after the mid

[32] The following data were provided by a former executive of Company A in the interview on September 17, 1993.

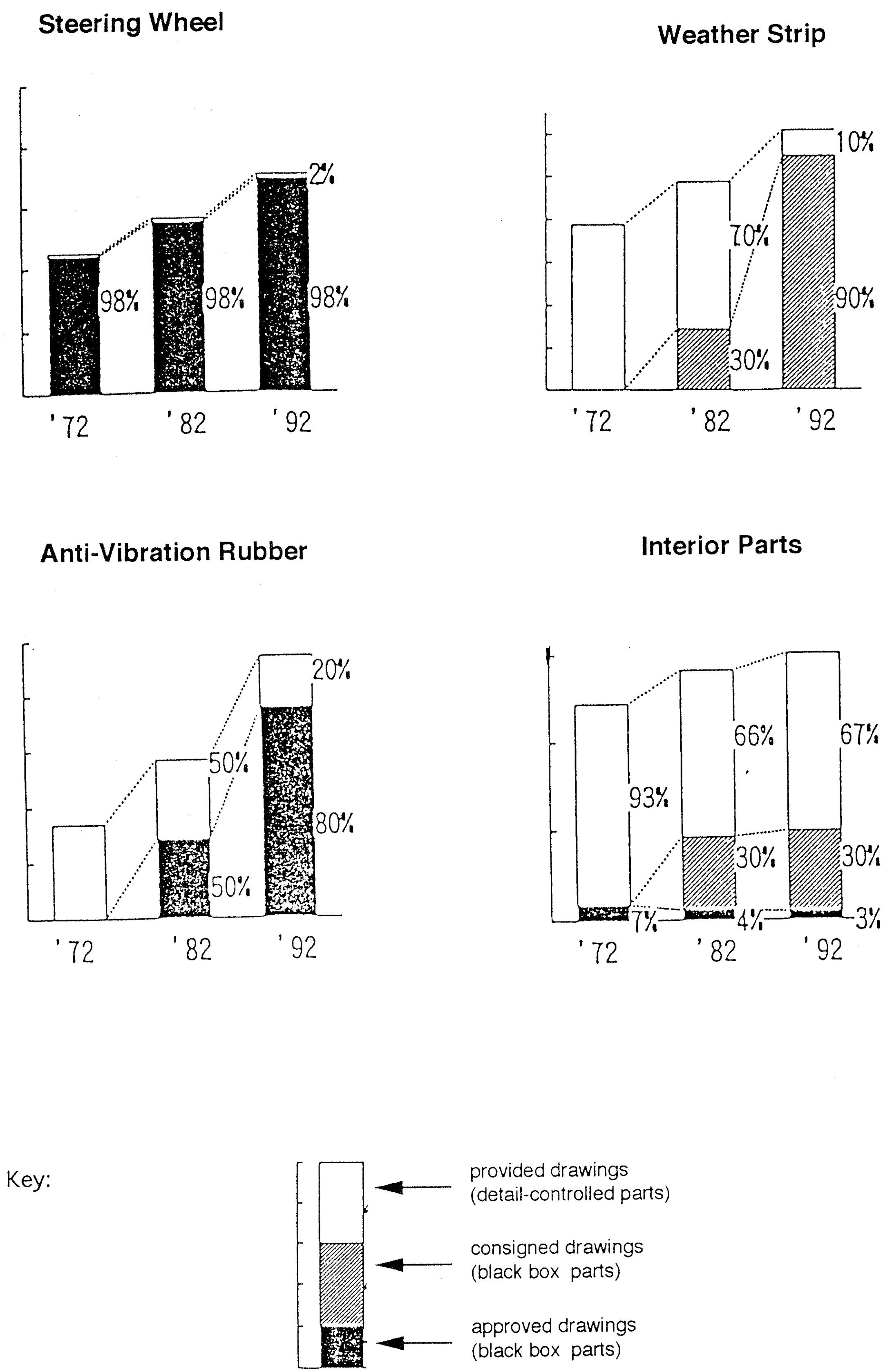
[33] Note that these data are based on the number of engineering drawings. The fraction of approved drawings in terms of purchasing cost is much higher, as parts cost per drawing is much higher in the case of approved drawings (mostly subassembly) than in the case of provided drawings (mostly piece parts). See, also, Clark and Fujimoto (1991).

Figure 10 Number o Parts Drawings by Types Types of Transactions (Company A)



Souce: Company A.

Figure 11 Number of New Drawings per Year by Types of Transactions and Items (Company A)



1980s is likely to have created pressures to rely more on engineering resources of the suppliers (see, also, figure 9 again)[34].

5.5 Nissan in 1980s: Bench Marking and Institutionalization

Although Nissan's black box parts system may have already originated before the war and were diffused in the 1960s, similarly to Toyota, the system is said to have lacked a coherent and effective system of formal procedures. It was in 1986 to 87 that Nissan finally established a system of formal procedures for black box parts, which Nissan called "New Approved Drawing System."[35] This was apparently a part of Nissan's efforts to renovate its organization in the late 1980s.

Preparation for this shift started in the early 1980s, when the Japanese auto industry was recovering from the second oil crisis. This was a period when Nissan switched from restrictive to expansive strategies in production and product mix. Thus, Nissan was predicting a rapid increase in product development work load. At the same time, Nissan's managers were concerned about the fact that its approved drawing system was not as developed as that of Toyota. After a bench-marking study of Toyota's practice, for example, it was revealed that Toyota's inputs to black box suppliers (a few pages of specification documents with rough sketches) were much simpler than those of Nissan (a roll of fairly detailed specification drawings). This implied that Nissan's black box parts system consumed more in-house engineering resources, and that it was more restrictive against suppliers' efforts to make their parts design easier to manufacture. It was also pointed out that the timing of specification freeze at Nissan was late compared with the case of Toyota.

After a series of analyses, Nissan's engineering administration department proposed the following revision of the black box parts system in the mid 1980s (Figure 12).

- The old approved drawing system used "specification drawings" or "shiyozu" (incomplete drawings that the suppliers were expected to complete) as inputs to the suppliers[36]. The new system abolishes specification drawings and introduces "specification instruction form" (shiyo teiansho), which was closer to Toyota's "Design Request Form." In this way, suppliers could enjoy more design discretion to apply their technological expertise to the deigns.

- Division of responsibility for development tasks between Nissan and the suppliers was not clear in the old system. In the new system, it was proposed that "Design Task Assignment Table" and "Check Sheet" clarify

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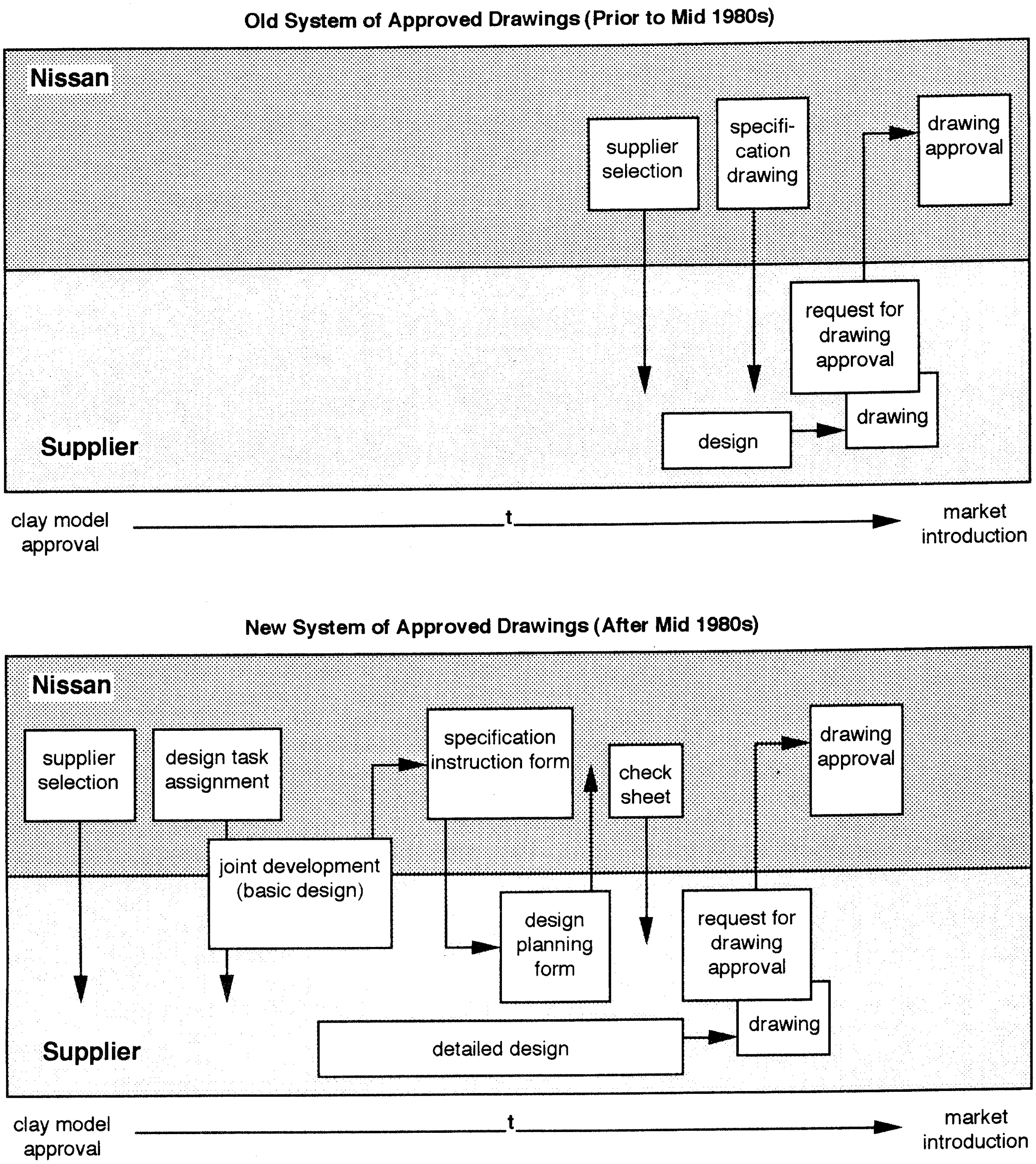
[34] Another survey that the author conducted for several product managers of the Japanese auto makers in 1993 also shows that the most of the respondents were feeling that the auto companies increased their dependence on the suppliers' engineering resources between the mid 1980s and 1993, and that the fraction of approved drawing parts in total number of parts procured also increased during the same period.

[35] This section is based mainly on an interview with Ryo Hatano, General Manager of Material Purchasing Department, Nissan (May 8, 1993).

[36] Note that the black box transactions at Nippondenso at the initial stage were also based on such drawings or "shiyozu" supplied by the auto makers. The inputs from the automobile makers were subsequently simplified to specification documents, though. See section 4.4 of this paper.

Figure 12 Nissan's Adoption of New Approved Drawing System (Mid 1980s)



Source: Nissan

responsibility of each party. This measure was expected to eliminate duplication of development work between Nissan and the suppliers.

- Responsibility for quality assurance was not clear in the old system, either. In the new system, it was proposed that the approved drawing suppliers take full responsibility for functionality of the component as a unit.

- In the old system, timing of supplier selection was relatively late. In the new system, supplier selection is made much earlier (around the end of the product planning phase), which gives supplier longer lead time for component design.

- Specification drawings were unilaterally submitted to the suppliers in the old system. The new system added a period during which Nissan and the supplier jointly develop specifications.

Overall, the new approved drawing system adopted some of the practices that Toyota had already had: relatively simple specification form, clear division of responsibility for quality assurance, early supplier selection, and joint development of specifications. At the same time, Nissan managers expected that the new system would save engineering person-hours for its in-house engineers.

There were some controversy inside Nissan as to the shift to the new system. Some argued that technological hollows might be created in the new system, in that its engineers would cease to be real engineers by stopping to make engineering drawings (Japanese design engineers tended to believe that capability of drafting was a prerequisite for good engineers). However, the argument that Nissan would have needed thousands of additional engineers to maintain the old system when it had to expand its product line overshadowed such concerns, according to a Nissan manager[37].

In this way, Nissan introduced a new black box parts system, which was similar to that of Toyota in many senses in the 1980s. As discussed later, Nissan group suppliers adopted the approved drawings system almost as early as Toyota's counterparts, but the content of the system was significantly different from each other. In fact, it might be the case that Nissan was among the last in the Japanese auto makers in adopting the Toyota-style approved drawing system, because there has been a tacit agreement that Toyota group suppliers (e.g. Nippondenso) supplied parts to any Japanese auto makers except Nissan group assemblers, while Nissan group suppliers made an opposite move excluding the Toyota suppliers (See "type 1" and "type 2" in figure 13). Although independent and neutral suppliers (type 3 in figure 13) might have acted as intermediaries that transferred the essence of the Toyota-style system to Nissan, it is likely that the separation of Toyota and Nissan supplier groups was at least partially responsible for Nissan's delay in adopting an more effective black box parts system. In other words, the partial separation on supplier networks between Toyota and Nissan may have hampered the transfer of Toyota-style black box parts system to Nissan.

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[37] Nissan's purchasing staff were not concerned about the possibility that early selection of suppliers would deprive of their price negotiation power, because they were confident of reliability of their target cost system.

Figure 13 Patterns of Assembler and Supplier Relationship (1990)

Type 1: Toyota's and Nissan's Suppliers Are Separated

Starter

	assembler \ supplier	A	B	C	D	E	F
Toyota group	Toyota	■					
	Daihatsu	■					
	Hino	■	■				
others	Mitsubishi	■				■	
	Suzuki	■		■		■	
	Honda	■		■			■
	Mazda	■				■	■
	Isuzu	■			■		■
Nissan group	Fuji (Subaru)	■				■	■
	Nissan Diesel		■			■	■
	Nissan					■	■

Radiator

	assembler \ supplier	A	B	C	D	E	F	G
Toyota group	Toyota	■	■					
	Daihatsu	■	■					
	Hino			■				
others	Mitsubishi	■	■					■
	Suzuki	■	■		■			
	Honda	■	■		■			
	Mazda	■	■					■
	Isuzu	■				■		
Nissan group	Fuji (Subaru)	■						■
	Nissan Diesel					■		■
	Nissan						■	■

Type 2: Many Dedicated Suppliers

Seat

	assembler \ supplier	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Toyota group	Toyota	■	■													
	Daihatsu			■												
	Hino				■										■	
others	Mitsubishi					■	■								■	
	Suzuki							■	■	■						
	Honda									■					■	
	Mazda										■	■				
	Isuzu				■								■		■	
Nissan group	Fuji (Subaru)				■									■		
	Nissan Diesel														■	■
	Nissan														■	■

Type 3: Oligopoly by Neutral Suppliers

Head Lamp

	assembler \ supplier	A	B	C
Toyota group	Toyota	■	■	■
	Daihatsu	■	■	
	Hino	■	■	
others	Mitsubishi	■		■
	Suzuki	■		■
	Honda	■		■
	Mazda	■		■
	Isuzu	■	■	
Nissan group	Fuji (Subaru)	■	■	
	Nissan Diesel	■	■	■
	Nissan	■	■	

Shock Absorber

	assembler \ supplier	A	B	C	D
Toyota group	Toyota	■	■		
	Daihatsu	■	■	■	
	Hino	■			
others	Mitsubishi	■	■		
	Suzuki	■	■	■	
	Honda		■	■	
	Mazda	■	■	■	
	Isuzu	■	■		
Nissan group	Fuji (Subaru)	■	■		
	Nissan Diesel	■	■		
	Nissan	■	■		■

Source: Industry experts.

■ Transactions exist as of 1990. In-house production is omitted for simplicity

According to the study by Clark and Fujimoto (1991), the fraction of black box parts in total procurement cost was consistently high among the Japanese auto makers[38]. It is thus likely that the diffusion process of the approved drawing system among the Japanese auto makers came to a conclusion by the late 1980s.

5.6 <u>Diffusion of the Black Box Parts System: Survey Results</u>

Let us now turn to the result of the author's survey discussed earlier. The survey asked approximately when the companies started various activities related to black box parts practices. The results are generally consistent with the above description of the diffusion process (figure 14):

- The peak period of the institutionalization of the approved drawing system, as well as actual diffusion of the system within each supplier, was the late 1960s. The next wave came in the 1980s (diagrams 2 and 3 of figure 14).

-The peak time for the start of informal requests from the auto makers was the early 1960s. The pattern of the informal requests tended to precede that of formal institutionalization (diagram 1).

- Many of the first-tier suppliers started to regularly hire college graduates for engineering jobs during the 1960s. Establishment of formal engineering sections or divisions in and outside the factories tended to precede full-scale activities in product engineering (diagrams 4, 5 and 6).

- The suppliers started to make engineering proposals and conduct VA-VE activities mostly after the 1970s(diagrams 7 and 8).

These results seem to be consistent with the foregoing argument that the adoption of approved parts system on the supplier side was influenced by the rapid increase in engineering work load on the side of the auto makers (figure 9), and that the formal establishment of the system may have been preceded by informal participation of suppliers in automobile product development.

What about the difference between Toyota and Nissan? Figure 15 compares the timing of institutionalization of approved parts system between Toyota-related suppliers (including the independent type supplying both to Toyota and Nissan) and Nissan group suppliers. Apart from the difference in the content of the black box parts system between the two group, which this paper discussed earlier, the pattern of timing in introducing some kind of approved drawing system is fairly similar, although the Toyota-related suppliers tended to be slightly earlier[39]. Also, there is a small pike in the early 1950s in the case of Toyota-related suppliers. This, however, does not

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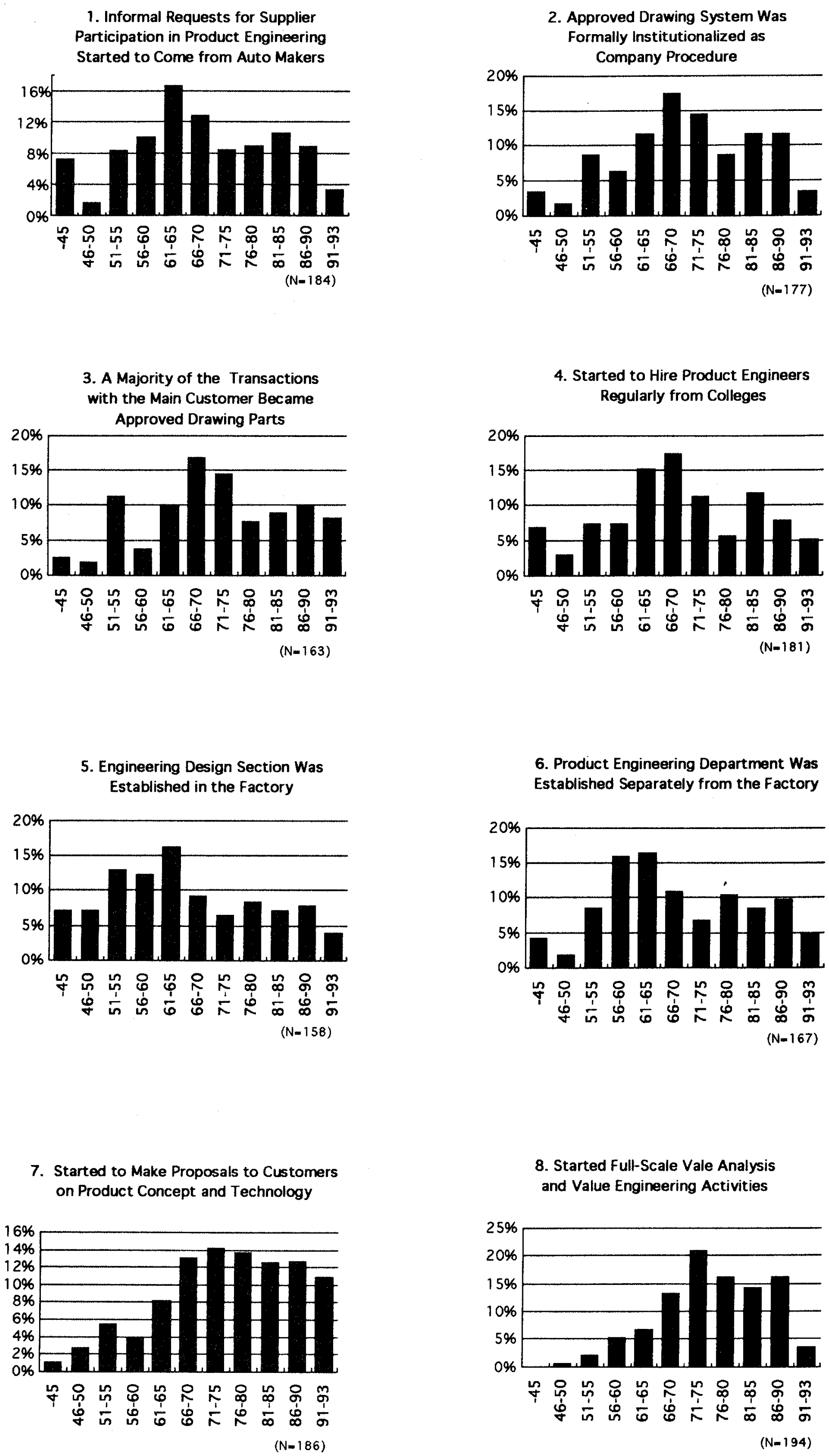
38 Average fraction of black box parts in procurement cost among the Japanese samples (N = 12) was 62%, with a standard deviation of 17%. Toyota was not among the highest in this figure; Nissan was above the Japanese average.

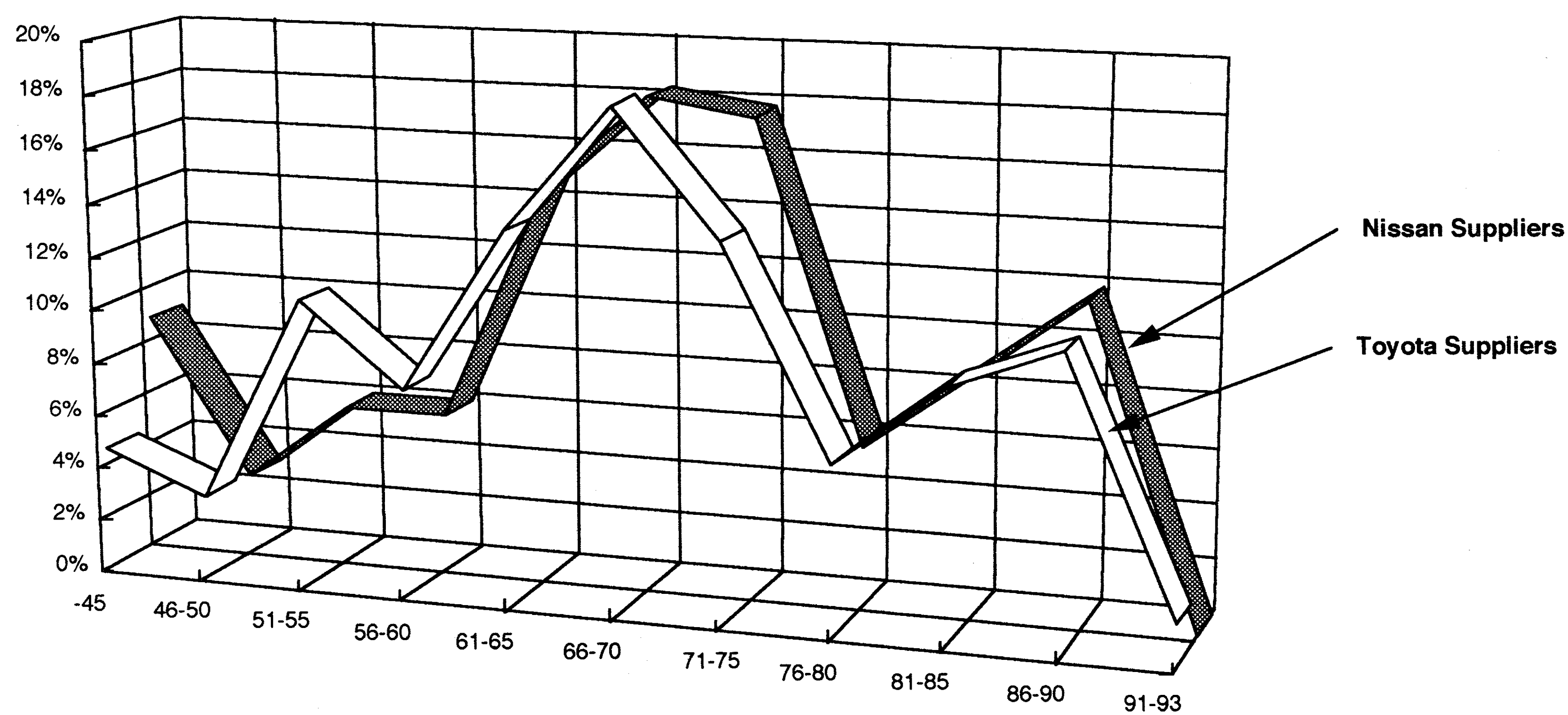
39 Note that there are some Nissan suppliers that started the approved drawings system before the war. Considering that many of the Nissan suppliers are located in the eastern part of Japan, where there were some major aircraft makers (e.g. Nakajima), they may have been the prewar aircraft parts suppliers. Further investigation is needed on this. See, also, section 4.4 of this paper.

Figure 14 The First Timing of Supplier's Engineering Activities



Source: A questionnaire survey by the author in 1993.

Figure 15 Comparison of Toyota-Related Suppliers and Nissan Suppliers in the Timing of Institutionalization of Approved Drawing System



Note: Toyota-related suppliers include those whish supply both Toyota and Nissan

Source: A questionnaire survey by the author in 1993.

seem to be the diffusion effect from Nippondenso[40]. Again, the origin of the black box parts system (Toyota version) and its diffusion seem to be generally separate both in logic and timing.

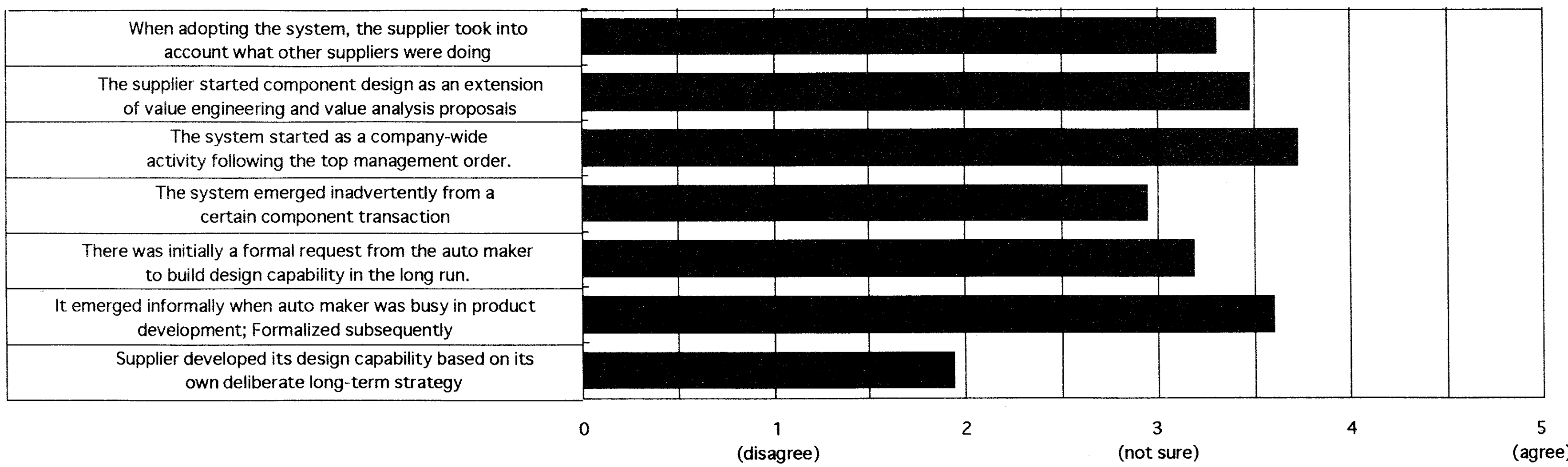
Finally, the survey asked the respondents whether they agree with several statements describing the origin of the approved parts system at each company (figure 16). Although most of the answers were rather indecisive, the result seems to indicate that, in many cases, the system was established not because of each suppliers' deliberate strategy or rational calculation, but because of a top-down policy following the informal requests from the auto companies at their busy time, or as an extension of VA-VE activities.

40 Among the 15 respondents that said they introduced the formal approved parts system between 1951 and 1955, two were supplying mainly to Toyota, two were mainly for Nissan, five were neutral in supplying both, and six were dealing mainly with other Japanese companies such as Honda, Suzuki, Daihatsu, Mitsubishi, and large truck companies. In other words, there is no particular concentration in the Toyota group suppliers.

Figure 16 Opinions about the Origin of the Approved Drawing System at Each Company

(Agree = 5 point; Disagree = 1 point; Not sure = 3 point)

N = 184



Source: A questionnaire survey by the author in 1993.

6 A Case of Evolution of Black Box Parts: Company B

6.1 Company B (Interior Parts): from 1960s to 90s

In order to examine more closely how each supplier's design capability evolved over time, Company B, a suppler of interior parts, was chosen as a case[41]. This company maintains a close tie to Toyota in terms of capital participation and transaction[42]. Established in the early 1960s, the company itself is fairly new, and it started with virtually no deign capability. Besides, interior parts are relatively difficult to adopt the black box parts system because of its close interdependence with total vehicle design. Thus, the case seems to provide an informative case of how a "late comer" in black box parts system gradually accumulated design capability step by step.

There are two dimensions of design capabilities: width and depth. By width of design capability we mean the number of transactions that adopted the black box practice. In fact, the width of company B's design capability increased by increasing the number of Toyota's models for which company B supplied certain parts based on the black box arrangement. It also expanded its types of parts that adopted the black box system from parts category X to category Y[43]. By depth of design capability we mean the level of knowledge base. In this regard, company B gradually added capability of detailed parts design, sub-assembly design, testing, styling, and basic design and planning. The case indicates that the process of design capability building takes significant time and requires a careful management and long term perspective.

6.2 Width of Design Capability

Let us now examine the case more closely. Figure 17 shows the product line of Toyota for which company B adopted black box parts system in parts X and/or Y.

- Starting from parts X for the first generation Publica, Toyota's entry class model, company B expanded its width of business as Toyota expanded its product line.

- Company B's business with Toyota continued, but switching of suppliers did happen at the level of individual transaction for various reasons[44].

- Company B started its black box arrangement with a single product, Crown, and gradually expanded the range of Toyota models that adopted this arrangement.

- The company also expanded its products that adopted the black box system from parts X to parts Y.

Another important event is that, prior to its inception of black box transactions with Toyota, company B started to supply parts X for folk lift trucks of Toyoda

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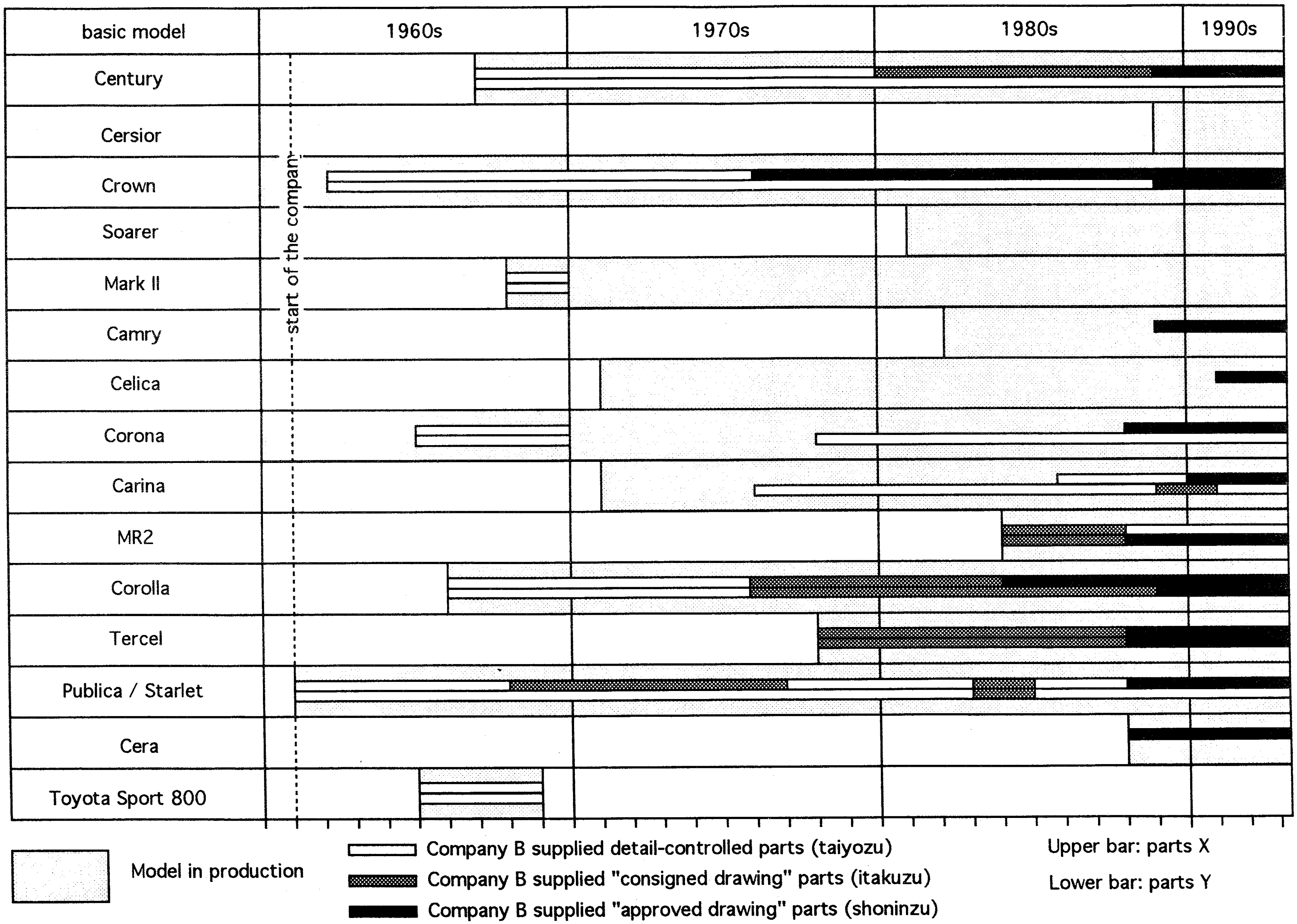
[41] The author greatly appreciate cooperation of anonymous managers of company B.

[42] Toyota holds a minority share of company B's stock. Virtually all of company B's business is related to Toyota group.

[43] There are two major parts categories that company B is engaged in: X and Y. X occupies a majority of company B's sales.

[44] As for parts X, company B was one of several suppliers (and one of two major ones) for Toyota.

Figure 17 Company B's Transactions with Toyota (Passenger Car)



Automatic Loom, a Toyota group company, based on the approved drawings system in the mid 1960s. The parts for the folk lifts were simpler and technically easier, but this case gave company B an important lesson: shifting from detail-controlled to approved drawing system is not easy, as it means owing responsibility for design quality assurance. Although the original motivation of this move was to reduce company B's dependence on the automobile business, it served company B, after the fact, as a "rehearsal" of the approved drawing business with Toyota, which was more demanding than the case of the folk lifts.

6.3 Depth of Design Capability

The depth of company B's design capability also increased in thirty years. Figures 18 and 19 explains how the company acquired skills necessary for black box parts, such as detailed parts design, prototyping, detailed assembly design, testing, industrial design, basic design, and product planning. A brief history of the capability building is presented as follows.

- In the early 1960s, company B started its business with a small engineering department with three to four people. The unit had capability of engineering administration (i.e. handling given drawings), basic production engineering (i.e., making bill of materials based on Toyota's parts drawings), and prototyping, but it had virtually no capability of designing and drafting its products. The company was fully dependent on detailed drawings provided by Toyota.

- In the mid 1960s, three years after the establishment of the company, company B started to send its young engineers to Toyota's interior engineering department for one or two years each. They worked at Toyota' premise, learning not only product technologies but also Toyota's engineering process itself. The young engineers from company B first did miscellaneous jobs assisting Toyota's interior engineers, but Toyota soon started to give them a set of jobs related to company B's target product. They acquired capability to draw assembly drawings of parts·X around that time.

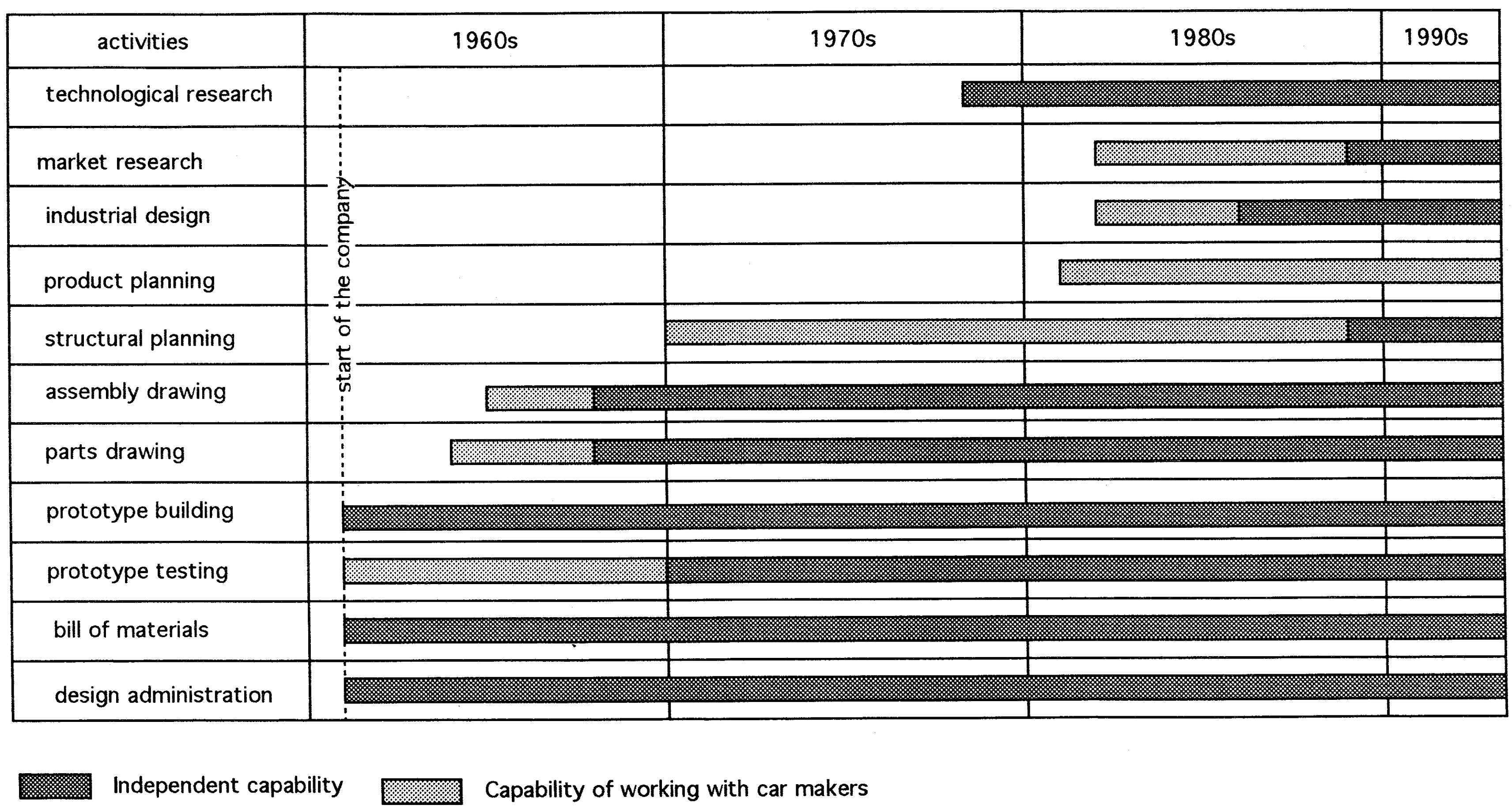
- In the mid 1960s, as mentioned earlier, company B started a job for Toyoda Automatic Loom on approved drawing basis.

- In the late 1960s, company B started to get some jobs from Toyota on consigned drawing basis. Toyota still took final responsibility for quality assurance, but the arrangement was more like a joint development, in that the engineers from both companies often worked at Toyota's premise. The amount of work under this arrangement grew rapidly in the early 1970s.

- In the 1970s, company B established a system to test and evaluate prototypes, following Toyota's testing standard. As Toyota still took quality assurance responsibility, though, the testing conducted by company B was "consigned testing.

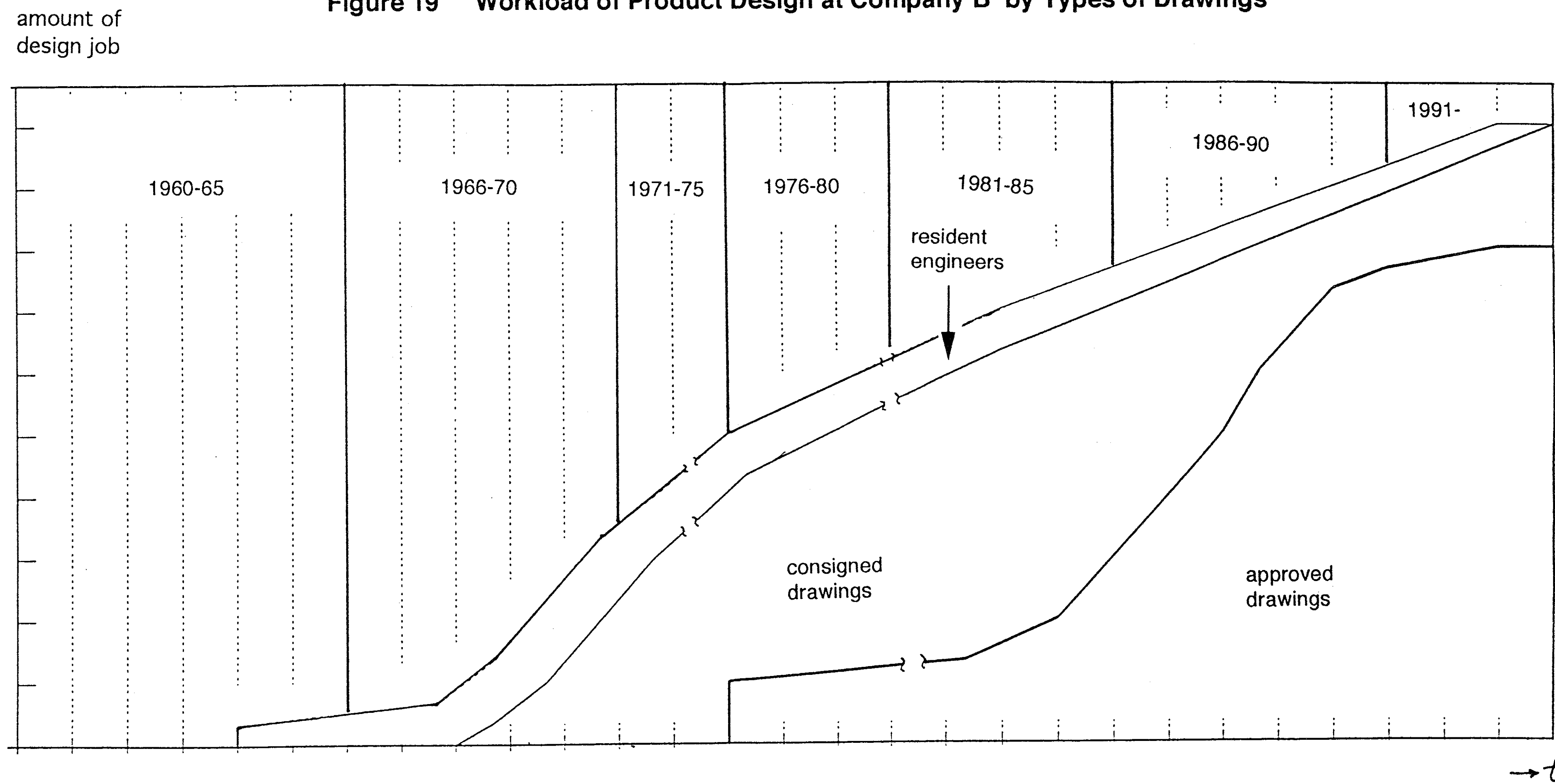
- In the same period, company B's engineers started to participate in the process of setting detailed specifications, basic designs and test

Figure 18 Step-by-step Acquisition of Engineering Capability at Company B



The folk lift business was omitted for simplicity.

Figure 19 Workload of Product Design at Company B by Types of Drawings



Note: This diagram represents an image held by the company staff rather than actual data.
Source: Company B.

standards[45]. Thus, company B gradually acquired capability of not only detailed design but also basic design (i.e. specification setting).

- Also, in the early 1970s, company B's engineers got capability of making assembly drawings of parts Y, ten years later than the case of parts X.

- In the mid 1970s, fifteen years after the establishment of the company and eight years after it started consigned drawings, company a finally started to do business with Toyota on approved drawings basis. It started this system in one model. The switch from consigned to approved drawings meant that the company had to take a risk as to quality assurance, but it acquired more discretion to design manufacturable parts. For Toyota, this also meant further reduction of its own engineering work load.

- During the same period, company B's engineers working at Toyota's premise started to be treated as full-fledged engineers, which seems to reflect improvements of the former's engineering capabilities.

- In the late 1970s, company B won Toyota Quality Control Prize (Toyota's version of Deming Prize), which implied that company B was now ready to move to the approved drawings system and become a specialist parts supplier. The prize thus triggered rapid growth in company B's design jobs. Also, the company started up its research activities around this time. Its initial research efforts were concentrated in the claims in terms of functionality of part X.

- Also, in the late 1970s, the company made quality assurance department, including test engineers, separately from its engineering department. It also started to dispatch test engineers to Toyota.

- In the early 1980s, company B extended its engineering capability further upstream, participating in a part of Toyota's product planning. It also started market studies on durability and functionality of parts X independently or jointly with Toyota.

- In the early 1980s, company B started to hire industrial designers. A few years later, it started to dispatch designers to Toyota, as in the case of design engineers and test engineers.

- In the mid 1980s, jobs based on approved drawings started to grow rapidly. This was partly because approved drawing system was adopted in the company's two major products: parts X for Toyota Corolla and Crown. The shift completed in the early 1990s.

- In the late 1980s, company B started to do structural planning for Toyota on consigned drawing basis. This virtually meant working jointly with Toyota's engineers to make basic designs, from which company B made detail drawings on approved drawing basis. The number of resident engineers was reduced during the same period.

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45 Such a specification is called structural planning, which consists of a number of documents and rough drawings and is made by translation of product planning, an upstream document.

In this way, it took company B over twenty years to acquire full capability of black box parts with dozens of engineers and designers. Interactions between Toyota and company B were carefully managed with long term perspectives. For example, resident engineers meant that the engineers of company had access to the engineering rooms of Toyota (i.e., beyond the reception area). Of about two hundred suppliers that Toyota dealt with, less than one hundred had such arrangements of dispatching resident engineers.

It should be also noted that consigned parts (itakuzu) functioned as a kind of "rehearsal" that paved the road to company B's transformation to an approved drawing (shoninzu) parts supplier. In other words, whereas company A chose either consigned or approved drawings depending upon the nature of the components (see section 5.3), company B shifted its emphasis from the former to the latter over time.

7 Summary and Implications

7.1 Summary: Logic for the Emergence of Black Box Parts

The case of black box parts practice in the Japanese auto makers provides a rich case of how a group of manufacturing firms build new capabilities over time. Foregoing discussions seem to indicate that the system emerged and evolved over time by a complicated combination of driving forces surrounding the industry. As the case of company B suggests, the process of developing black box design system requires step-by-step collaboration and tenacious capability building by both the assembler and the supplier. Also, as shown in table 1, the present case seems to indicate that a combination of the logic of system emergence, such as environmental constraints (historical imperatives), entrepreneurial visions and knowledge transfer, explains partly how the practice was originated and developed. In any case, it should be noted that the black box parts system was not a practice that the Japanese auto makers adopted from the Ford system in America unlike many other elements of the Toyota-style system (Fujimoto and Tidd, 1993).

7.2: Origins

As for the origin of black box parts system, historical evidences make us infer that the transactions between Toyota and Nippondenso in 1949 was probably one of the origins (if not the only origin) of the black box parts practice, particularly its Toyota version.

Historical imperatives, or technological constraints, seem to have played an important role here: First, before the war, Toyota could not find decent electric parts suppliers in Japan, so it was almost forced to design and make such parts in-house; Second, after the war, Toyota had to separate the electric parts factory for its own survival; Third, when Nippondenso was created in 1949 as a result of the separation, Toyota found that it had to rely on engineering capability of Nippondenso, as virtually all the electric engineers had moved to the separated company. In this way, the historical imperative that Toyota lacked technological capability for electric parts appears to force Toyota to apply the approved drawing (i.e.. black box parts) system to its transactions with Nippondenso from the beginning.

This story implies that the black box practice emerged not because of rational calculation by the automobile companies (at least before the fact), but by a

Table 1 Summary of the Emergence Logic for Black Box Parts System

Logic	Empirical Evidence
Rational Calculation	● Before the trial: Benefits of black box parts are not well predicted ○ After the fact: Toyota was quick in institutionalizing what it inadvertently tried and found to be effective.
Environmental Constraints (Technological Dependence)	● Few suppliers had engineering capability in the 1930s and 40s. ○ Toyota - Nippondenso case: Toyota lacked electric parts engineering capability as it separated Nippondenso in 1949
Environmental Constraints (Insufficient Number of Engineers)	● Black box parts practice originated before the model proliferation period. ○ Survey result: The peak time of diffusion of the black box parts system coincided with model proliferation period in the late 1960s. ○ Respondents of the survey tended to agree that high engineering work load of the auto makers triggered the shift to black box parts. Interviewees at Nissan, Company A and Company B, at least partially, agreed with this hypothesis.
Knowledge Transfer	● Ford and other US mass producers did not have black box parts, and thus they were not the source of the practice. ⊜ Prewar aircraft industry in Japan may have been a source of the back box practice. ○ Indirect knowledge transfer (benchmarking) from Toyota to Nissan in the 1980s. ○ Rapid diffusion of black box parts practice among the Japanese first-tier suppliers (survey results)
Entrepreneurial Vision	● No clearly stated comments on the black box parts system by Toyota's executives were found in the formal company history ○ Kiichiro Toyoda's vision of growing specialist parts vendors after the war might have facilitated the development of black box practice.

Note: ○ = evidences consistent with the hypothesis

● = evidences contradicting the hypothesis

⊜ = inconclusive

"Random trials' was omitted from the table.

set of constraints or historical imperatives imposed on the auto makers. The auto companies apparently realized the benefit of this practice much later, when engineering workload started to soar as a result of product proliferation in the 1960s.

Inter-industrial Transfer of the practices in the prewar locomotive and /or aircraft industries may also explain partly the origin of the black box parts system. Transformation of supplier proprietary parts (e.g., tires and paints) to black box parts may be another passage to the new system. Further investigation is needed to examine theses hypotheses, though.

Entrepreneurial visions (e.g., conceptualization and visions by Kiichiro Toyoda, Taiichi Ohno, etc.) did not seem to have played a decisive role in the case of black box parts, unlike some other cases (see Fujimoto and Tidd, 1993). As indicated in the foregoing discussion, there are some evidences that the founder of Toyota Motor Manufacturing had a vision of nurturing parts specialist suppliers even prior to the war, when Toyota had to make many parts in-house. Although Kiichiro's remarks did not refer to black box parts system, it is possible that what he meant by "specialist" was a parts maker that also had research and development capability for designing a certain type of parts. To the extent that Kiichiro's "specialist" concept implied capabilities of parts design, it is possible that Kiichiro's vision of the supplier system served as a catalyst, if not driving force, for subsequent development of the black box practice. However, in the case of black box parts, the entrepreneurial visions were not unequivocally and explicitly stated by the executives and managers, unlike the case of Just-in-Time and Total Quality management.

7.3 Diffusions

The foregoing case also indicates that the *historical imperative* of high growth with limited resource inputs in the product engineering area of the auto companies (i.e. shortage of in-house engineers at the model proliferation era) created constant pressures to subcontract detailed component engineering wherever possible.

From the suppliers point of view, the black box arrangement meant a great opportunity to develop its own design capability, build up a technological entry barrier against the auto makers' efforts to make the parts in-house, gain some quasi-rent, and survive as a first-tier parts supplier, although it was accompanied by the risk of taking full responsibility for quality assurance. Competitive pressures from the rival suppliers also accelerated their efforts to build up design and engineering capability in order to match up with their competitors' efforts. Thus, once the auto makers started to offer the opportunities of shifting to the black box arrangement, the suppliers tended to have rational reasons to accept the offers, as long as they had enough managerial capability to do so.

Transfer of knowledge and managerial resources between suppliers (e.g. from Nippondenso to other suppliers), between assemblers (e.g. from Toyota to Nissan), as well as between an assembler and a supplier (e.g. from Toyota to company B), was a key engine for diffusion of the black box practice. Thus, originating presumably from the transactions between Toyota and Nippondenso in the late 1940s, the black box practice prevailed rapidly during the high growth area of the 1960, and the diffusion process approached to a conclusion within the Japan in the 1980s. The diffusion is now in progress across the boarder: from Japan to the US.

The diffusion of the black box parts system in general, in terms of timing, was not much different between Toyota and Nissan. However, it was the content and effectiveness of the system in which the two companies differed for a long time. Thus, it was in the 1980s that Nissan modified its black box system closer to the Toyota version.

To sum up, the origin and evolution of the back box practice, which is one of the sources of the competitive advantages of the Japanese auto industry of the 1980s, may be explained by a combination of the system emergence logic discussed in section 3, including historical imperatives and inter-firm and inter-industrial knowledge transfers, rather than rational calculation or deliberate strategic choices prior to the events. While the system, after it was established, might have turned out to contribute to competitive advantage, the benefits were not clearly recognized by the firms when it was emerging. After the companies learned from their unintended trials, however, some of the firms started to adopt the new system more intentionally, deliberately, and institutionally.

Thus, to the extent that an ex-post rational system emerged out of unintended imperatives or constraints, it may be meaningful to explore and analyze the logic of system emergence. More importantly, It was this capability of systematizing the new elements after the trials, rather than that of rational calculation, that seems to explain the difference in the content and effectiveness of the black box parts systems between Toyota and Nissan up to the mid 1980s. This makes us raise the last question: what is the source of the inter-firm differences in performance and capabilities?

<u>7.4 Implication: Patterns of Capability Building</u>

The foregoing case of the evolution of black box parts system may provide some insights from the view point of dynamic aspects of manufacturing firms' core capabilities (Chandler, 1990; Teece, et al., 1992; Leonard-Barton, 1992; Kogut and Kulatilaka, 1992, etc.).

- *Long-term Evolution of Capabilities:* The suppliers accumulate capability of component engineering through long-term collaboration between assemblers and suppliers. The process needs step-by-step enhancement of design and engineering capabilities both in width and depth.

- *Competition Based on Capability Building:* As the case of company B indicates, suppliers making similar components competed with each other in terms of gaining component design capability. Thus, short-term price competition (i.e. bidding) is not the only mode of competition. In the long run, competition of building engineering capabilities becomes crucial. In other words, companies compete for building inter-firm differences in capability and performance in their favor.

- *Limit of Capability in Rational Calculation:* The foregoing cases indicated that Toyota was more effective than some other makers in designing and implementing the black box parts system. Is this because Toyota was more capable of predicting the effectiveness of the system than others? It seems unlikely. The cases in this paper seem to indicate that even Toyota could not predict effectiveness of the black box parts system prior to its trials, and that Toyota, forced by historical imperatives and environmental constraints in mane cases, tended to make initial trials in an unintended manner. Thus, the inter-firm difference in the results does not seem to be caused mainly by the inter-firm difference in capability of rational calculation.

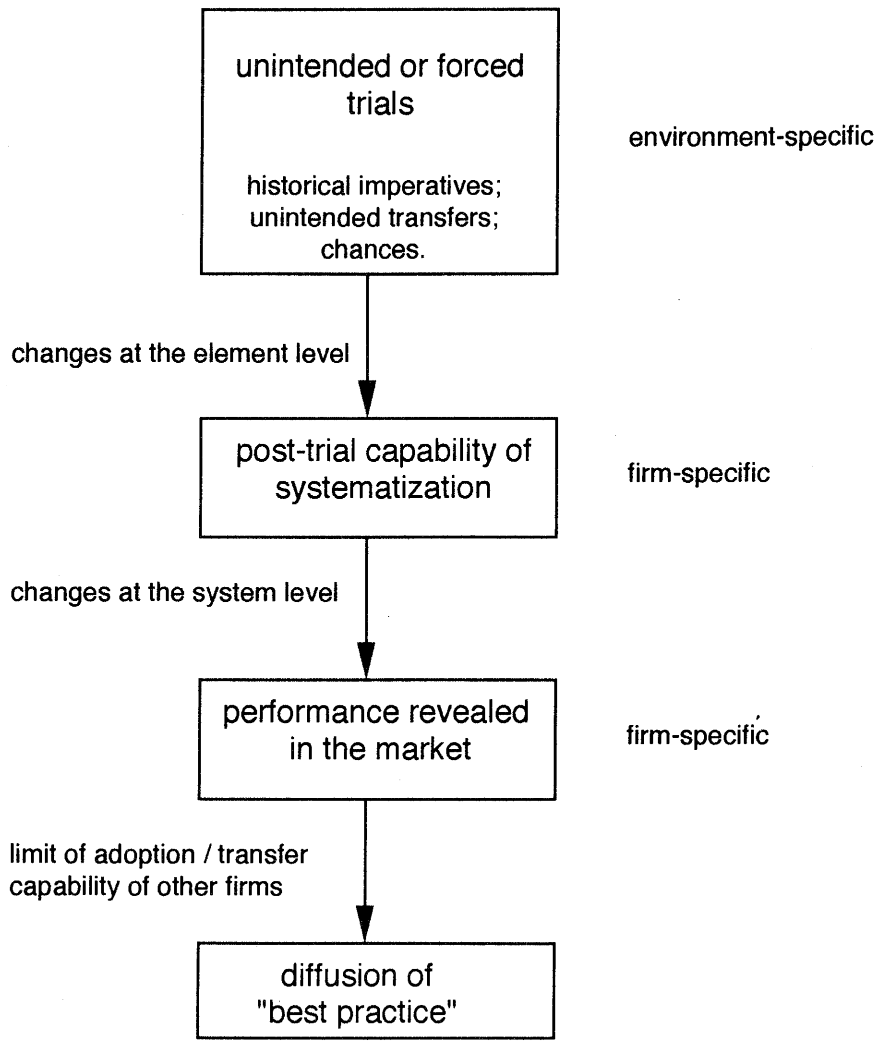
- *Inter-firm Gaps in Capability of Systematizing the Successful Trials:* What Toyota could do better than its rivals seems to be not so much rational calculation before the trials as systematization and institutionalization <u>after</u> the trials. Opportunities for making certain trials for new systems came to other companies as well. For example, Toyota and Nissan both faced the same kind of historical imperative by which they were virtually forced to rely partially on suppliers' engineering resources. They both made trials on this direction. However, as Nissan itself found in the mid 1980s, the effectiveness of the resulting system was significantly different. This seems to be because Toyota had capability of quickly learning from what it inadvertently tried, understanding the core benefit of the trials, institutionalizing them as a set of formal procedures, and diffusing them within the company and throughout supplier network better than its rivals.

To sum up, inter-firm differences in certain *dynamic capability* seems to have created competitive differences among the auto makers in terms of utilizing suppliers' potentials in component engineering. However, it was not so much the capability of making better choices before the trials, as the capability of learning from the trials that the firm already made for whatever the reasons. That is, *post-trial capability*, rather than pre-trial capability (e.g. rational calculation or visions), seems to have been crucial in the foregoing case of the emergence of the effective system. Although the current paper focused only on the emergence of the black box parts practice, there seems to be other elements of the Toyota-style production-development system as well, in which post-trial capability was the key for their evolution.

There are various ways in which a company differentiates its capability competitive performance in a dynamic way. In some cases, differences in entrepreneurial visions may create the competitive advantage of a firm (Okouchi, 1979). Capability of rational calculation may be critical in other cases. In still other cases, pure luck may give some firms certain advantages. In the current case of black box parts practice, though, it seems to be the capability of systematizing the unintended trials that created Toyota's advantages over its rivals (Figure 20). Dynamic capabilities of creating visions, calculating rationally, or imitating from others tended to be by-players in this particular case.

The concept of "capability" in the dynamic aspect of manufacturing firms attracted much attention of both academic researchers and practitioners in recent years, but the linkage between the concept and empirical findings does not seem to be that clear so far. In this regard, historical studies on a detailed aspects of manufacturing capabilities, such as the foregoing paper, may be able to contribute somewhat to further development of the evolutionary theories of capability building.

Figure 20 A Typical Pattern Observed in the Case of Black Box Parts Evolution



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