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Introduction

As U.S. and European automobile producers found their sales and profitability declining during the 1980s, numerous researchers launched studies that probed the management systems of these companies as well as compared their performances. Several studies found remarkably high levels of productivity and quality from a handful of producers primarily in Japan. Strategic and organizational explanations of elements behind the performance of Japanese firms focused on the integration of workers and suppliers as well as innovative manufacturing and quality-control techniques [15, 27, 9, 10, 34, 2, 21, 23].

But excellence in manufacturing is useful only if firms are able to deliver products that customers want to buy. The evidence, however, strongly suggests that Japanese automobile producers not only have been efficient in manufacturing. They have also consistently designed and engineered a rising number of attractive and technically sophisticated products, with the result that Japan passed the United States in automobile production in 1980 and by 1987 boasted five of the top dozen auto manufacturers in the world (Table 1) as well as the automakers with the highest growth rates since 1970 (Table 2). High productivity and quality may also be as characteristic of Japanese efforts in product development as they are of Japanese efforts in manufacturing management. It thus seems essential for researchers as well as managers or policy makers concerned with global competition in automobiles and other industries to understand better two sets of issues that go beyond what we have already learned about manufacturing: (1) What differences exist among Japanese, U.S., and European firms in managing product development in the automobile industry? And (2) what do these differences suggest about factors that appear to make product-development organizations successful in general, both in project management and product marketability?

This article discusses the conclusions and methods of several researchers that have already responded to questions such as these. The number of these studies examining performance in product development is still neither as large nor as systematic as research in manufacturing, although enough work has been done to prompt a review and critique of existing research. The first section of this article thus examines major variables in studies of auto product development conducted during 1985-1990 and offers a model for conceptualizing and measuring product development from three interconnected vantage points: product strategy; project structure and process (organization and management); and product as well as project performance. The second section reviews specific results from these studies, focusing on the relationships of product strategy with performance and then structure and process with performance. The third section critiques these studies in order to outline specific issues that seem to require further inquiry. The concluding section reviews what we have learned about product development in the automobile industry and summarizes the challenges for additional research at the empirical and theoretical levels.

1. Variables in Auto Product-Development Research

A consideration of major variables examined in studies on product development in the automobile industry is useful to understand what factors researchers have deemed important. This discussion also helps clarify the meaning of terms researchers have used.

1.1 Groups of Variables: As outlined in Figure 1 and Table 3, most researchers have relied on major variables that fall into three groups: (1) *product strategy*;

(2) *project structure and process*; and (3) *project or product performance* (inputs, outputs, and market share), at the individual-project and multiple-project (firm) levels. Researchers have also assumed a causal relationship such that (i) product strategy determines the product-development agenda and thus task requirements; (ii) task requirements directly or indirectly affect the structure and processes a firm might use to organize and manage product development; and (iii) overall product strategy and task requirements, as well as the management structure and process for individual projects, directly or indirectly affect project performance and market responses to products.

These variables are complicated to specify, measure, and interpret. On the one hand, it is difficult to limit the number of internal and external factors that affect the process of conceiving, designing, engineering, and then preparing to mass-produce a new product; customer responses to products may be equally or more complex in nature. On the other hand, causal relationships among even a selected number of variables may still be unclear because of interdependent effects. Management researchers have been concerned with these and other issues for years and a vast literature exists on guidelines for modelling and managing research and product development, though less has been written that presents comprehensive theories and empirical research linking strategy, structure, and performance.[1]

Another issue is that, when analyzing the effectiveness of product development, most studies have looked primarily at individual projects. Yet most firms in the automobile industry, as in many other industries, offer multiple products that complement one another and form a corporate-level portfolio or hierarchy of products. This reflects a particular aspect of

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[1] A bibliography useful for reviewing existing studies is [1]. Other recent review articles, books, and anthologies, from a variety of perspectives, include [3, 18, 19, 20, 31, 36, 37, 38].

performance in product development that cannot be analyzed at the project level alone: the cumulative effect of technical complexity in multiple projects done at least partially simultaneously. These tax engineering resources throughout the firm and its suppliers or partners and limit either the total number of new products a manufacturer can develop in a certain period or the quality of the firm's new products. Therefore, perhaps the most critical question for managers and researchers is not how well a company performs in an individual project but how well it manages a *series* of projects over time. Some researchers have indeed been sensitive to this issue as well as proposed different sub-variables to probe deeper into product strategy, structure, and performance, as discussed below.

1.2 Product Strategy: An important aspect of product strategy discussed in much of the research is the *product concept,* which may include the pricing segment (luxury versus economy) or size of a model, as well as the degree of new or sophisticated technology incorporated into different components. For example, a product aimed at a high-priced segment of the market, with demanding performance objectives, should increase task requirements and thus the demands on the engineering resources available to the firm.

Another major dimension pertaining to task requirements is the individual *project strategy,* which includes *project (or task) complexity* and *project scope.* Project complexity has been defined as the number and type of components designed anew in a single project. This is determined in an automobile, for example, by the number of body types, engines, features, or options. Project scope, on the other hand, generally refers to the percentage of unique components a manufacturer designs from scratch in-house for a given model, as opposed to reusing components from other models, the immediate predecessor of a new model, or from a supplier's inventory of proprietary parts. Thus high project complexity and scope require more design tasks for a firm and should have a negative impact on productivity, although other effects may also influence performance. In some instances, utilizing existing components may constrain designers or involve various transactions within a firm or with suppliers that end up requiring more time than building parts from scratch.

1.3 Structure and Process: Structure and process include the internal organization and management of product development as well as the utilization of external resources. With regard to the internal organization, researchers have examined whether a firm manages through functional structures (such as separate departments for engines or body designs) or through integrated projects; whether the project reflects a formal organization or an informal task force; and how many functions or activities, as well as personnel, a project involves. Other dimensions that primarily measure process variables include the degree of overlapping in the development stages, coordination among functions or phases, and coordination among and within projects such as through information processing of some sort.

With regard to external engineering resources, researchers have examined the roles of suppliers as well as the relationships between the internal organization and external organizations. For example, a manufacturer may develop all the specifications for a component and simply subcontract its production, it may define only functional specifications and let suppliers do the detailed design, or it may incorporate parts proprietary to the suppliers into its products. The use of external resources has also been considered a dimension of task requirements in the sense that using outside firms may reduce the task requirements the internal organization has to manage.

1.4 Performance: Researchers have considered at least three types of performance variables. One has been *input* measures. In manufacturing analyses, researchers compared labor hours or person-years per vehicle, unit costs per vehicle, value-added per worker, or total factor productivity (labor and capital). In product development, researchers have focused on two dimensions: (1) how many engineering hours and, correspondingly, (2) how long of a "lead time" a firm requires to introduce a new product from concept generation to pilot production. These measures of time are far from trivial: Each day of delay for an average automobile has been estimated to cost a firm about $1 million in lost profits, thus amounting to hundreds of millions of dollars in potential additional profits for companies that are merely four or five months faster to market than competitors with comparable products [7, p. 1260].

Second, some researchers have considered specific *output* measures. (1) *Design quality* includes everything about a product that is visible or perceivable to the customer, such as technical performance, styling, or the match of the product with the target customers' tastes. (2) *Design manufacturability* refers to the efficiency of the design from the viewpoint of the production organization, such as how easy it is to assemble. (3) The *total number of new or replacement products* a company completes within a certain period of time, modified by other variables such as project complexity and scope, defines the total performance of the firm in the form of added or modified products, rather than focusing on the outputs or inputs of an individual project.

Third, some researchers have viewed the *market performance* of models individually and companies overall as critical indicators of product-development effectiveness, based on the assumption that a major objective of any development effort is to produce products that sell. A common measure relatively easy to calculate is market or production share or growth in share. Another measure might be profit per unit, since this would capture the premium a firm can charge for its products, although independent researchers have apparently had problems collecting this type of confidential data from companies. Profitability is also difficult to measure accurately and systematically across firms with potentially different accounting practices, especially since many costs directly and indirectly affect product development, such as spending in basic research or at suppliers.

As a final point, it seems that researchers relying on one or more of these performance variables have generally believed that inputs and outputs--primarily engineering hours, lead times, the number of new products, and design quality -- affect market performance. But since no one element seems to capture efficiency or effectiveness in product development completely, at least some studies have resorted to multiple measures in order to increase the reliability of their comparisons.

2. Major Findings

The following review of studies done between 1985 and 1990 illustrates more specifically the main observations from researchers based on their analyses of variables introduced in the previous section. The discussion here focuses on two sets of concerns that underlie this research: the measurement and relationship of (1) product strategy with performance, and (2) structure and process with performance.

2.1 Product Strategy with Performance: Clark, Chew, and Fujimoto, both in individual and joint publications between 1987 and 1989 [6, 7, 8, 13], measured performance using data from a total of 29 projects in 22 manufacturers from the U.S., Japan, and Europe. Due to confidentiality agreements, they did not associate data with individual firms but instead presented regional or group averages. Their results indicate that Japanese manufacturers, in general, displayed higher development productivity in terms of engineering hours and lead time. After being adjusted by task requirements and usage of external resources (outside suppliers), average engineering hours of Japanese, the U.S., and European manufacturers were approximately 1.2, 3.5 and 3.4 million hours per new model (2.7, 4.9, and 6.4 when adjusted for project scope -- see [6], p. 744). The average lead times were 42.6, 61.9, and 57.6 months, respectively, as well as 71.5 months for European high-end specialist producers (Table 4).

In order to make the productivity data comparable among the projects studied, Clark, Chew, and Fujimoto adjusted for the possible influence of development tasks on productivity using such dimensions as size of the vehicle, price, new parts ratio, the number of body types for a given model developed in a particular project, and supplier contributions. The results showed significant correlations between all of these task dimensions and engineering hours, indicating that, for example, larger or higher-priced (luxury-segment) models required more engineering hours to develop. Lead time also had a significant correlation with these variables, although the positive correlation between lead time and the number of body types was very small, suggesting that projects developed additional body types in parallel with the main body type and with little extra time required overall.

A special strength of the research was the attempt to measure the engineering resources of suppliers as another dimension affecting task requirements in individual projects and the use of information on supplier participation to adjust the nominal productivity numbers. These data show that, in design, Japanese firms were more dependent on suppliers than the U.S. or European manufacturers (a finding that parallels research indicating that Japanese auto manufacturers have made greater use of suppliers in manufacturing as well -- see [9, 10]). In particular, Japanese firms relied on suppliers to perform detailed engineering for components whose functional specifications they developed in-house (see Table 4). Overall, as Fujimoto [13] calculated, the suppliers' share of costs in engineering parts were 51%, 14%, 37%, and 32% in the projects of the Japanese, U.S., European volume-producers, and European specialist firms, respectively. These differences had positive correlations with unadjusted productivity in terms of engineering hours and lead time. In other words, greater use of suppliers reduced project scope (defined as the percentage of unique parts developed in house by the manufacturer) and, accordingly, the number of in-house engineering hours as well as the amount of time projects required.

Clark elaborated on the data from the original project in a 1989 article [7], focusing on the earlier result that showed Japanese projects used more unique parts than U.S. or European firms, which theoretically may increase design quality but add time and costs in development, unless fitting old parts into new designs creates additional coordination that increases engineering time. Japanese projects had more unique parts and higher engineering productivity, as seen in Table 4, apparently because they made such extensive use of suppliers (whose engineers also seemed to be more efficient than in-house engineers) that the total amount of new design they had to do in house was about 9% less than in U.S. projects and 5% less than in European projects. Overall, greater supplier involvement appeared to account for about one-third of the Japanese advantage in engineering hours and four to five months of their advantage in lead time.

Fujimoto [13], elaborating in 1989 on results discussed earlier [6], measured design quality using several variables that included a technical defect rate, repurchase intentions of customers, and a subjective evaluation by automobile magazine and journal experts. While these attributes are extremely difficult to determine accurately and consistently, Fujimoto employed multiple measures to increase the reliability of his conclusions. In addition, he supplemented the indicators of design quality with data on market performance measured by changes in market share. Based on various measures, Fujimoto thus concluded that projects from two Japanese and two European manufacturers had higher design quality than other manufacturers. The products of these four producers also showed the highest growth rates in market share, suggesting that higher design quality as defined in this study positively affects market performance.

In addition, Fujimoto explored the relationship between productivity and design quality. For this analysis, he introduced a product-strategy variable as a moderator, in order to indicate whether a manufacturer is a volume producer or a high-end specialist. A volume producer he defined as a firm that develops less expensive models than high-end specialists and differentiates its products from competitors by adopting a unifying concept for a family of products that can accommodate changes in customers' lifestyles and tastes. In terms of basic performance, volume producers also try to follow and match the standards set by high-end competitors. On the other hand, high-end specialists differentiate their products by performance in well-established functional criteria, which Fujimoto argued are relatively stable over time.

Among the 22 organizations studied, Fujimoto defined four manufacturers in Europe as high-end specialists and the others as volume producers. Of the four manufacturers that had the highest design quality, two were volume producers and two were high-end specialists. The subsequent analysis indicated that the two volume manufacturers with the highest design quality also had the highest productivity, while the two high-end specialists with the highest design quality had the lowest productivity. His interpretation of these data seems to make sense: In order to achieve high design quality, volume producers have to respond quickly to the performance standards competitors set as well as changes in customer tastes. In addition, because price is one of the most important factors on which volume producers compete, they probably try to minimize engineering hours, which are closely associated with development costs. In contrast, high-end specialists achieve their competitive advantages through functional performance of their products and maintaining this appears to be their first priority, hence more engineering hours and longer lead times may result in superior products functionally and thus positively contribute to higher market performance [13].

In 1988, Sheriff [33], using publicly available data and surveys sent to individual firms, measured performance by focusing on the number of totally new or modified products a manufacturer introduced into the market, with additional data measuring task requirements of individual projects.[2] Replacements or additions determine the life cycle of existing car lines as well as the number of new lines a manufacturer offers. The number of model lines a company offered also correlated closely with its total sales volume. The specific assumption of this study, although not tested with performance data such as market shares, was that shorter product life cycles for replacing existing models and adding new models provide an advantage in that faster firms can more quickly and broadly expand their product lines as well as

[2] Sheriff [33] defined a model as a car with completely unique outside sheet metal (skin) or with substantially modified sheet metal as well as a modified track or wheelbase. Therefore, he did not consider essentially similar models that had different nameplates (such as similar Buick and Oldsmobile, or Ford and Lincoln models) as different products.

introduce new technology or better meet customer demands as these change over time.

For all major automobile manufacturers in the U.S., Japan, and Europe, Sheriff proceeded to calculate the replacement rate for existing models,[3] the expansion rate of new models,[4] and the average product age. According to this analysis, between September 1981 and May 1988, nine Japanese manufacturers introduced 94 new products and recorded a replacement rate of 135% and an expansion rate of 60%. For three U.S. manufacturers, these numbers were 31, 60%, and 55%, and for seven European manufacturers (excluding specialty producers), 30, 70%, and -23%. As a result, the total number of models and the average product ages for the Japanese manufacturers were 73 products and 2.1 years, compared to 36 products and 4.6 years for the U.S. producers, and 47 products and 4.6 years for the Europeans. Six specialty producers (BMW, Jaguar, Mercedes, Porsche, Saab, and Volvo) had 24 products with an average age of 5.7 years (Table 5).

These data suggest several observations. First, Japanese firms replaced their models more frequently, consequently their products, on average, were newer. Second, dividing total new products during 1981-1988 and the number of models offered as of 1987-1988 by the number of companies indicates that the Japanese and U.S. industries were roughly as productive (10 new products per firm) but, since U.S. firms kept more older products, they had more offerings

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[3] To calculate this percentage, Sheriff took the total number of new models a company introduced in this period, subtracted the number of new models that were new product lines rather than replacements for existing models, and then divided by the number of models the firm had in the base year, 1981.

[4] To calculate this percentage, Sheriff divided the number of totally new models introduced to expand the product line by the number of models the firm had in the base year.

per company in 1987-1988. In contrast, the European and specialty producers lagged, especially in new products. Third, it appears that, since Japan had the largest number of companies and they were highly productive in producing new products (totally new and replacement versions of existing lines), Japanese firms were able to offer a huge number of products, which probably helped the Japanese industry overall gain in global market share (see Table 1).

Among individual firms, Honda (including the Acura division) had the most outstanding performance, with a replacement rate of about 275% and an expansion rate of approximately 125%. No other company was close on both dimensions; Honda also was the most rapidly growing firm between 1970 and 1987 among automakers with more than 1,000,000 units of production in the late 1980s (see Table 2). Toyota, Suzuki, Mazda, Nissan, and Daihatsu followed as the next best-performing group, roughly in that order, with replacement rates of around 150% and expansion rates between 25% and 70%. A specialty producer, Porsche, was the worst performer by these two measures, with no replacements or additions (Figure 2).

Sheriff's study also provided evidence that these differences in performance probably were not primarily determined by variations in task requirements of individual projects. He concluded this after analyzing the average task requirements using a company-wide measure of project scope (the number of projects a single company undertook in the period of time analyzed) and project complexity. Project complexity he calculated through an index, based on interviews with product-development engineers and his own experience as a Chrysler employee, that assigned weights to changes made in major exterior, interior, and platform components, with adjustments upward for each additional body style or wheelbase [33, p. 118].

According to these measures, the European projects had the highest average complexity, followed by the Japanese and specialty producers, and then the U.S. producers. However, the differences among the projects from these firms appeared very small compared to the number of projects, where the Japanese firms had a distinct advantage. Even grouping the European volume producers with the specialty producers, the Japanese completed twice as many projects during the same time period, of roughly comparable complexity in terms of the amount of changes introduced into their models. Compared to the U.S. producers, the Japanese managed three times as many projects and these were, on average, of higher complexity (Figure 3). Among individual firms, Opel and Ford of Europe stood out as having the most complex projects, while Chrysler and GM had the least complex (Table 6).

Fujimoto and Sheriff compared their data and explored interrelationships in a joint 1989 paper [14]. This study indicated that, at the manufacturer level, development productivity in terms of lead time and engineering hours had a positive correlation with the number of new products, expansion rates, and replacement rates. They also tested the relationship between these dimensions and market performance measured by growth in market share. Variables such as short lead times, the number of new products, the expansion rate, and the replacement rate, all had positive correlations with market growth, as Sheriff theorized in his 1988 paper. Fujimoto and Sheriff also found no significant relationship between engineering hours and market growth, which supported their hypothesis that engineering hours influence development costs but not market performance.

Another study of product concept at the manufacturer's level, though more conceptual and case-oriented than statistical, was done by two Japanese researchers, Sakakibara and Aoshima [32]. Similar to Fujimoto [13], they assume that the "wholeness" of a firm's product lines as determined by consistency in product strategy leads to better market performance.[5] This study categorizes product strategies into one of two types: strategy A, a "continuous spectrum"; and strategy B, a "discrete mosaic." Strategy A views the whole market as a set of stratified, continuous segments, whereas strategy B views the market as a set of unrelated, discrete and multiple segments.

It follows that new-product development under strategy A targets existing customers of the company's products and attempts to provide them either with replacement models or models that will entice them to move up from a lower-priced to a higher-priced product. In order to implement this approach successfully, new development needs to consider how any one model fits into the whole set of product lines the firm offers in terms of product concept and price positioning, so that individual models have characteristics in common with other cars from the same manufacturer and fit neatly into a hierarchy of product lines. On the other hand, development under strategy B is not constrained by the need for a new product to fit into a hierarchy with other models. Rather, it focuses on producing models that are uniquely differentiated from other models, either from the same manufacturer or competitors, so that the new model can attract customers from any segment of the market. Sakakibara and Aoshima argued further that, in either strategy, the level of consistency or wholeness of the entire set of product lines determine market performance. They then illustrated this hypothesis by analyzing Toyota as a successful example of strategy A, Honda as a successful example of strategy B, and Nissan as an unsuccessful example due to an inconsistent strategy (at least in the decade or so up to 1988).

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[5] Actually, this notion in the auto industry dates back to Alfred P. Sloan's strategy for General Motors during the 1920s and afterwards of having multiple product divisions with different nameplates and pricing levels to attract and hold customers. See [5, 35].

2.2 Structure and Process with Performance: A first observation researchers have made with regard to structure and process is whether an organization is organized by functions or by projects. Clark, Chew, and Fujimoto [6, 13] measured this variable by evaluating the authority and responsibility of the product manager, who is supposed to manage a project across functions and throughout all phases. They conclude that an organization with no product manager is a functional organization. Their study then goes on to categorize the other organizations into four groups, according to the level of authority and responsibility of a product manager, from "heavyweight" to "lightweight" product manager.

According to their definitions, the heavyweight product manager has extensive authority and formal responsibility for both concept creation and engineering, including product and process engineering. Concept creation covers the aspects of product development where project members collect information from customers or on the market and then attempt to match or anticipate market needs. The lightweight product manager has authority and responsibility limited to engineering functions and does not have any say over concept creation and other marketing aspects of product development.

The results from this study of 22 project organizations indicated that Japanese manufacturers, in general, have "heavier" heavyweight product managers than their U.S. or European counterparts. As indicated earlier, the Japanese projects in this study also exhibited the highest productivity in product development measured by engineering hours and lead time. Furthermore, there seemed to be a correlation between organization types and design quality. The two highest design quality producers were Japanese volume producers; they also had the two heaviest heavyweight product managers among the 18 volume producers.

On the other hand, among high-end specialists, one of two European manufacturers that produced the highest scores on design quality had a lightweight product manager, while the other had a functional structure, suggesting that lightweight managers or functional organizations may also be useful in producing quality designs, at least for specialist producers.[6] In terms of the correlation between organization types and product-development productivity, the study indicated that organizations with fewer engineering hours and shorter lead times tended toward the heavyweight side of the organizational spectrum, while those with more engineering hours and longer lead times tended to be organized by function.

Another indicator of coordination in project organization that researchers have discussed is the degree of overlapping in development stages from concept generation to pilot production, as well as the quality and intensity of communication exchanges among the varicus stages. Clark, Chew, and Fujimoto [6] again led the way in studying this systematically. They found that Japanese projects, in addition to their superior performance characteristics in general, had higher overlapping ratios (pp. 756-761). For example, as described further by Fujimoto [13] and summarized by Clark and Fujimoto [8], Japanese projects on average started advanced engineering (development of major functional parts, such as an engine or transmission) within one month of starting the concept-generation phase and four months before product planning (translation of the product concept into specifications for product engineering that cover elements such as styling, layout, major component choices, and cost targets). The

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[6] This observation corresponds neatly with discussions of organizations that emphasize the usefulness of a functional structure for cultivating specialized skills. For a summary of literature on organizational theory and organization design, see [16].

Japanese projects also required considerably shorter periods for each phase of development, thus accounting for a shorter average lead time from concept to market and thus higher engineering productivity overall compared to the U.S. and European averages (Figure 4 and Table 7).

In addition, Clark, Chew, and Fujimoto found that the Japanese projects had more informal and intensive "information processing" among various stages that seemed to make this higher degree of overlapping possible and useful. They measured this information processing by the release of design specifications to body engineering, intra-R&D communications, and communications between R&D and production groups. In fact, they concluded that this combination of overlapping and good communications was necessary for high development productivity and directly contributed to Japan's shorter lead times and fewer engineering hours. U.S. projects, in contrast, had a medium level of overlapping, a low intensity in communications, and low productivity, while the Europeans had the least overlapping, relatively intensive communications, but still low productivity compared to the Japanese.

There were at least two other analyses of overlapping or communications interchanges. Sheriff, who compared the product-development organizations and schedules at Mazda and Chrysler, produced results nearly identical to those from the Clark and Fujimoto research. He found that Chrysler had a standard development schedule requiring 65 months from start to finish and 212.5 engineering months total, compared to 48 months lead time and 182 engineering months total at Mazda. These schedules also seemed to parallel closely the course of actual projects. The longer time at Chrysler came mainly from a lengthy schedule for styling-concept development (24 months for Chrysler compared to 9 at Mazda) and an average of 3 months more in each of 10 overlapping phases. Mazda, apparently reflecting different priorities, spent more time on styling detail development and process engineering than Chrysler [33, p. 78].

Three other Japanese researchers, Imai, Nonaka, and Takeuchi [17], analyzed the relationship between organization and development performance by studying a new product-development project at Honda for a small car that became extremely popular in Japan, the City. They also compared this with four other apparently successful Japanese product-development efforts in other industries. They did not study any of these projects statistically but claimed to find significant overlapping as well as loose control from top management and informal activities among the various functions, coupled with simple and challenging goals set by management. These approaches appeared to encourage coordination among the different functions or phases in product development as well as a high level of creativity and motivation among the project members. As a result, project teams seemed highly flexible and able to learn quickly as well as respond to market needs and technical challenges while developing creative, popular products.

As another dimension of product-development performance that may be determined by coordination among functions or with external resources, Krafcik [22] examined design for manufacturability (DFA) as a separate variable. He did not measure coordination variables or mechanisms, nor did he directly analyze the manufacturability of vehicles, but instead asked 19 automobile companies to rank competitors' products in terms of ease of assembly. Of eight companies that provided usable responses, four were European, two were Japanese, and the remaining two were American. Krafcik then compiled a ranking list. Toyota and Honda clearly stood out as leaders on this variable, at least as recognized by respondents, and were followed by Mazda, Fiat, Nissan, Ford, Volkswagen, and Mitsubishi. The worst companies in design manufacturability seemed to be

Jaguar, SAAB, and Daimler-Benz (Table 8).

Using the DFA index and a weighted average age of designs built in a plant (the age adjustment relies on the assumption that companies have built newer products with more attention to manufacturability issues), Krafcik also used regression analysis to determine that a 10-point improvement on the design index correlated significantly (at the 1% confidence level) with an increase in assembly-plant productivity of about 1.6 hours per car. This was a substantial percentage for the most efficient automobile producers, the Japanese, which averaged about 17 hours per vehicle in final assembly (based on a sample of 8 firms), compared to 21 hours for 5 Japanese plants in North America, 25 hours for 14 U.S. plants in North America, and about 36 hours for 22 plants in Europe.

3. A Critique of the Research

No one study of a phenomenon as complex as product development is likely to be complete. Researchers usually focus on particular objectives or use research methods that limit their analyses. The studies reviewed above, accordingly, all have limitations, and these provide many opportunities for additional research. The critique in this section again follows the authors, concentrating on how they have related product strategy as well as project structure and process with performance.

3.1 Product Strategy with Performance: A first general comment refers to the analysis of task requirements in the Clark, Chew, and Fujimoto as well as the Sheriff studies. These offer insightful but still somewhat imprecise measurements of overall productivity in product development. Clark, Chew, and

Fujimoto, for example, did not adequately treat the level of difficulty potentially associated with new components, measuring task requirements by the price of new models as well as product size, the number of body types, and the percentage of the number of parts or of their costs developed in-house. In theory, firms should be able to incorporate all their costs into prices. In practice, different firms have different skill and cost levels, while competitive pressures force companies to charge prices that the market will bear. Moreover, the number or cost of new parts, without independent estimates of difficulties in design, may not adequately represent complexity in task requirements, especially if costs are heavily influenced by the price of materials.

The analysis of task requirements in Sheriff's study is actually more precise than the Clark, Chew, and Fujimoto research because Sheriff included project complexity as a separate variable and measured this by analyzing different components. Sheriff, however, did not adequately explain how he arrived at the weights he used for different types of changes or components made in product development, consequently, his complexity measure appears rather subjective. In addition, Sheriff, as well as Clark, Chew, and Fujimoto, excluded engines and other advanced-engineering components developed in separate projects from their analyses, even though these place major demands on a firm's engineering resources and thus overall development productivity, require different kinds of product-development structures and processes, and play a critical role in determining the success or failure of a new product. But while neither study really offers a complete picture of product development, there is enough data to suggest that the number of projects undertaken in a given period may be more important to a firm's overall performance than the complexity of individual projects. As seen in Sheriff, for example, Honda presented the appearance of extraordinarily high productivity in the sense of replacing and expanding its product lines (see Figure 2). It also has grown fastest among major auto producers (see Table 2). Yet Honda has achieved these gains with relatively simple projects, ranking approximately 15th out of 24 producers (see Table 6).

A second general comment refers to the samples of the various studies and the levels of analysis. Clark, Chew, and Fujimoto examined mainly one project for each company, selected by the companies. Although they made valiant adjustments to arrive at a set of standard operations across each project, companies may not have selected representative projects (there is no way to tell). In addition, product development might vary considerably in concepts and task characteristics or complexity even within a single manufacturer's product lines. Consequently, a sample of one project per company does not say much about which company is consistently superior in product development and why, even though Clark, Chew, and Fujimoto had a large enough sample to generalize about projects in Japan, the U.S., and Europe. In contrast, a major strength of Sheriff's research is that it covers all projects within a company and allows both for generalizations about firms regionally and individually. Yet Sheriff lacks the detailed analysis found in Clark, Chew, and Fujimoto such as of engineering hours for each phase of development or the role of suppliers, among other information.

Sakakibara and Aoshima add some perspective to how firms formulate product strategy and perform at the manufacturer's level. But they focus their discussion on three cases and offer no formal categorizations of strategy, structure, or performance. Nor do they have a large enough sample to argue whether these patterns fit more manufacturers, in Japan or elsewhere. Companies might also disagree with their informal interpretations of product strategies.[7] Hence, an ideal study might combine the breadth of Sheriff and the conceptual perspective of Sakakibara and Aoshima with the detail and precision of Clark, Chew, and Fujimoto.

3.2 Structure and Process with Performance: In this category, there appear two general weaknesses in existing research and thus two promising areas for further study. First is a need to evaluate more precisely the usage or usefulness of external engineering resources, which, for product development, include non-consolidated subsidiaries, unaffiliated suppliers, outside engineering firms, and joint ventures or strategic alliances with other car manufacturers. Joint ventures in particular seem to have become an increasingly popular option for designing new cars, as seen in recent linkages of General Motors with Toyota, Isuzu, and Suzuki; Chrysler with Mitsubishi and Renault; Ford with Mazda and Nissan; and many other examples [42]. The Japanese for years have also relied heavily on subsidiaries and affiliated suppliers [9, 10].

Relying on manufacturing as an analogy, researchers might pay more attention to adjusting for differences in vertical integration among different projects, despite the difficulty of doing this. Sheriff 1988 ignored this issue completely, which means he either overestimated or underestimated the capabilities of individual firms. Clark, Chew, and Fujimoto did adjust for vertical integration and, as noted earlier, they found significant differences among regional samples, with the Japanese making considerably greater use of suppliers. Yet the primary focus of their research was on the internal

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[7] Honda management, for example, may indeed have introduced models in the Acura division to attract previous Honda buyers moving up to higher-priced models as well as to attract new buyers. The question remains, however, to what extent Honda has consistently tried to develop individual "hit" products as opposed to developing a hierarchy or family of models intended to share concepts and attract new buyers as they move upscale in income.

operations of new projects and regional averages; they paid less attention to external engineering issues and included several assumptions in their work that are probably not valid.

For example, these researchers divided components that suppliers participated in designing into two categories: supplier proprietary parts and black box parts. In the case of proprietary parts, suppliers did all the design work themselves. In the case of black box parts, suppliers received some of the specifications from manufacturers and then completed the details of the designs themselves. To simplify the analysis, they assumed that all suppliers worldwide shared 30% of the design work for black box parts. But it is difficult to believe there were no differences among the Japanese, U.S., and European manufacturers and suppliers, especially since other portions of their data showed clear regional differences and other studies of manufacturing and engineering performance demonstrated regional as well as firm-level differences. Nor did their study examine the role of independent engineering firms, which may play an important part in product development, especially in U.S. manufacturers.

Another area that needs further exploration is internal project management. The Clark, Chew, and Fujimoto reports indicated that, for volume producers, coordination by product managers in concept creation as well as in product and process engineering appear to affect performance in product development. They did not, however, explore in detail the mechanisms through which product managers contributed to higher design quality or higher development productivity in specific projects through different techniques for design-task partitioning and sequencing, which some researchers believe are critical to efficient and innovative product development [11, 40]. Therefore, their study leaves open alternative hypotheses for the same results because organizations with strong coordination by heavyweight product managers tended to be Japanese and better performance in product development may thus come from other factors peculiar to Japanese firms or engineers. Imai, Nonaka, and Takeuchi offered generalizations about effective product-development organizations that focused on Japanese advantages and explored several Japanese cases in considerable detail, although the small size of their sample, the absence of systematic measures of different variables, and the lack of comparative cases from non-Japanese organizations make it impossible to generalize confidently about the validity of their observations.

The one existing study on design manufacturability by Krafcik [22], which surveyed the opinions of producers regarding competitors' products on this dimension, leaves much to be desired. First of all, as pointed out earlier, he did not really measure design for manufacturability directly. Nor did he explore what factors promote design for manufacturability or measure coordination among functions or with outside firms. In addition, the sample of respondents was small, responses probably were highly subjective, and the survey focus, as in Krafcik's productivity research, centered on assembly operations, rather than components manufacturing and assembly.

More objective measures of design manufacturability as a variable might include the total number of components in comparable products, the number of production or assembly steps for a sample or components, the number of unique parts versus those standardized for different models, the number of special jigs and tools used in particular operations, or how and when firms incorporate production issues into the design process [41]. It also would be useful for manufacturers to understand the impact of design for manufacture on engineering productivity and lead times as well as on product performance in the marketplace, where, for example, more easily manufacturable designs might cost less over the life cycle of a product (even if they cost more in development) and be more reliable if they reduce parts numbers and potential manufacturing errors.

4. Conclusions

The automobile industry has benefited from superb studies in recent years not only of manufacturing but of product development, an area that seems to present unique difficulties in measuring strategy, structure, and performance. Many of the activities in product development involve considerable thinking, conceptualizing, experimenting, problem solving, and communicating, rather than simply assembling components or doing other relatively routine operations. Predicting market responses to new products presents another host of challenges. Nonetheless, the research cited in this article -- the contributions by Clark, Chew, Fujimoto, and Sheriff in particular -- has helped clarify and quantify many of the critical inputs, processes, and outputs for effective product development, although more work remains to be done.

4.1 The Empirical Level: The empirical observations that seem most useful in understanding how organizations effectively manage product development come from comparisons of firms and projects, because this has forced researchers to explain, based on large samples, why certain groups of projects (primarily from Japan) have performed better than others. There are several generalizations one can make about the Japanese based on research reviewed in this article:

Product strategy: (1) Japanese automakers had moderately complex projects, trailing the Europeans by a small margin but appearing more complex than U.S. projects [33]. (2) Japanese projects developed more unique parts, which may have improved design quality and eliminated problems in accommodating existing components into new designs [6, 7. 13]. (3) Japanese automakers expanded their product lines and replaced their products more often than competitors [33].

Structure and process: (4) Japanese projects had more heavyweight managers, phase overlapping, and good internal communications, compared to U.S. firms and then the Europeans [6, 8, 13]. (5) As in manufacturing, Japanese firms made much greater use of external suppliers, which appeared to be even more efficient than the manufacturers themselves in many operations as well as tightly integrated with the manufacturer's development organizations [6, 7, 13].

Performance: (6) Japanese automakers had a significant lead over U.S. and European competitors not only in manufacturing productivity but in product-development productivity, such as measured by engineering hours and lead time [6, 13] as well as the number of models replaced or added [33]. (7) Japanese automakers in general seemed to have more easily manufacturable products, and this appeared to boost manufacturing productivity [22]. (8) The fact that Japanese automakers were many in number as well as highly active and efficient in product development seems to account for much of Japan's high and rising global share of automobile production [33].

On the company level, several studies indicated that Honda, followed by Toyota, were the outstanding performers in product development by various dimensions. These dimensions included the number and scope of projects, expansion and addition rates, design for manufacturability, and management processes [17, 22, 33, 32]. In addition, both firms, and the Japanese in general, have shown extraordinary growth in production levels since 1970 (see Tables 1 and 2).

Researchers have also provided statistical evidence linking strategy, structure, and performance. For example: (1) High productivity in product development, measured by lead time and the number of new or replaced products, although not project complexity as measured by total engineering hours (including overlapping phases), as well as high design quality, appear to correlate positively with superior market performance [13, 14, 33]. (2) Projects that make extensive use of suppliers in the development process (even with high percentages of unique parts), utilize heavyweight project managers in a matrix structure, and contain overlapping of phases as well as good communication mechanisms, seem to be most effective in reducing total engineering hours and lead times or improving design quality [6, 7, 13]. (3) Similar to studies showing the same firms as leaders in both manufacturing productivity and quality [21, 24], leading volume manufacturers appear to combine high design quality with high development productivity [13].

Along with empirical and descriptive evidence, researchers have offered a variety of thoughtful explanations for their results. Companies that are faster in product development as well as more prolific, without necessarily making more complex products, apparently have better chances of attracting and keeping customers, and thus growing in market share. Fast and effective product development requires many different functions, phases, suppliers, and individual people; matrix structures, strong project managers, overlapping of phases, and good communication appear essential to achieve the proper balance of specialized skills and coordination and even compensate for extra effort required to develop unique components. And high productivity in manufacturing and product development both require the effective management of technology and people; accordingly, it is not surprising, at least to these authors, that excellent firms excel at both.

But while there is much that we now know, researchers still need to generate more precise and comprehensive measures in at least five areas: (1)

strategic requirements at the manufacturer's level, which can be linked to the project level and the individual product in the marketplace, in order to capture more completely the efficiency and effectiveness of an entire organization in product development; (2) task requirements at the project level, such as technical complexity, that covers all critical components of a new product; (3) use of outside engineering resources, which have become quite varied in the contemporary industry, extending from affiliated suppliers to strategic partnerships with unrelated firms and outside contractors; (4) internal project management, especially the role of product managers in influencing not only the schedule or budget of a project but elements traditionally seen as more difficult to analyze, such as design quality; (5) the organizational requirements of better design for manufacturability as well as the precise impact of this variable not only on manufacturing productivity but on development costs, maintenance or service costs, and product performance in the marketplace.

4.2 The Theoretical Level: A straightforward theoretical argument, perhaps best expressed in Sheriff [33], seems to have motivated most of the studies of auto product development discussed in this article. The common assumption is that shorter product life cycles and high development productivity provide an advantage not merely in allowing firms to replace and add models more quickly, giving them a wider market coverage and a potentially larger market share. Speed also appears to help firms bring new technology more frequently into products as well as adjust to market changes more rapidly than slower competitors.

Researchers have gone beyond this broad proposition to theorize about specific interconnections among strategy, structure, and performance. For example, we know that firms have various ways to compete, ranging from low-cost positioning, numerous types of product differentiation, market-niche focus, or some combination [28, 29, 16]. Firms operating on a global scale also need to incorporate concerns for different geographic markets into their planning and organizations [30, 43]. Once managers have decided in what markets to compete and how to proceed, they have another set of options for acquiring or generating the technological skills they need and then organizing product development and manufacturing, including internal structures and processes as well as use of outside suppliers [12]. The authors cited have implicitly or explicitly argued for the linkages expressed earlier in Figure 1: A firm's product strategy determines the task requirements of individual projects; task requirements should match the project organization and management (structure and process); and task requirements, as well as structure and process, affect project and product performance.

Two examples illustrate these interconnections. First, volume producers probably have a greater need to create highly productive product-development organizations, since they compete on the basis of market coverage with different model lines, rather than product differentiation at the upper end of the market, where specialist producers compete. Accordingly, there appear to be better and worse ways of managing projects, with heavyweight product managers, matrix structures, overlapping phases, and communication mechanisms apparently useful for quickly bringing together the range of skills and coordination needed to design a product for low-cost mass production. A more functionally oriented organization may be better to design a product for high-performance competition [17, 6, 13]. Second, firms can either focus on developing models that relate to each other as in a continuous spectrum or on producing individual "hit" products. The former strategy has the advantage of providing a mechanism for enticing buyers to move up to higher-priced, complementary models. The latter has the advantage of allowing product developers more freedom to be creative or innovative. Again, however, each approach appears to require a different type of product-development organization and process [32, 13].

Theoretically, as discussed in another long stream of literature, the appropriateness of the "fit" between a firm's strategic objectives and its organization should influence performance [see, for example, 5, 25, 4, 16, 39]. It would be unusual, for example, if a firm that wants a balance of technical excellence in its products with manufacturability achieves this without a very stable product design and manufacturing process or some sort of matrix organization that combines people with expertise in both design and mass production. Yet it is also true that many variables, both internal and external to the firm, and only some of which management can influence, may affect the performance of personnel in individual projects as well as the response of customers to particular products in the marketplace. Automobiles, which contain thousands of components and require hundreds of suppliers as well as several years to design and prepare for mass production, present much time and many opportunities for error as well as for consumer tastes to change and competitors to act.

There remains, consequently, a need for more precise, conceptual models that tightly connect a company's competitive positioning and product strategy with its development-organization structure and then with performance, at the levels of the individual project as well as the company overall. This is no simple challenge, although, to the extent companies can act to create stronger linkages among strategy, structure, and performance, the results of actual and proposed research such as discussed in this article should help managers better understand product development and manage this more effectively.

Figure 1. Major Variables in Product-Development Research

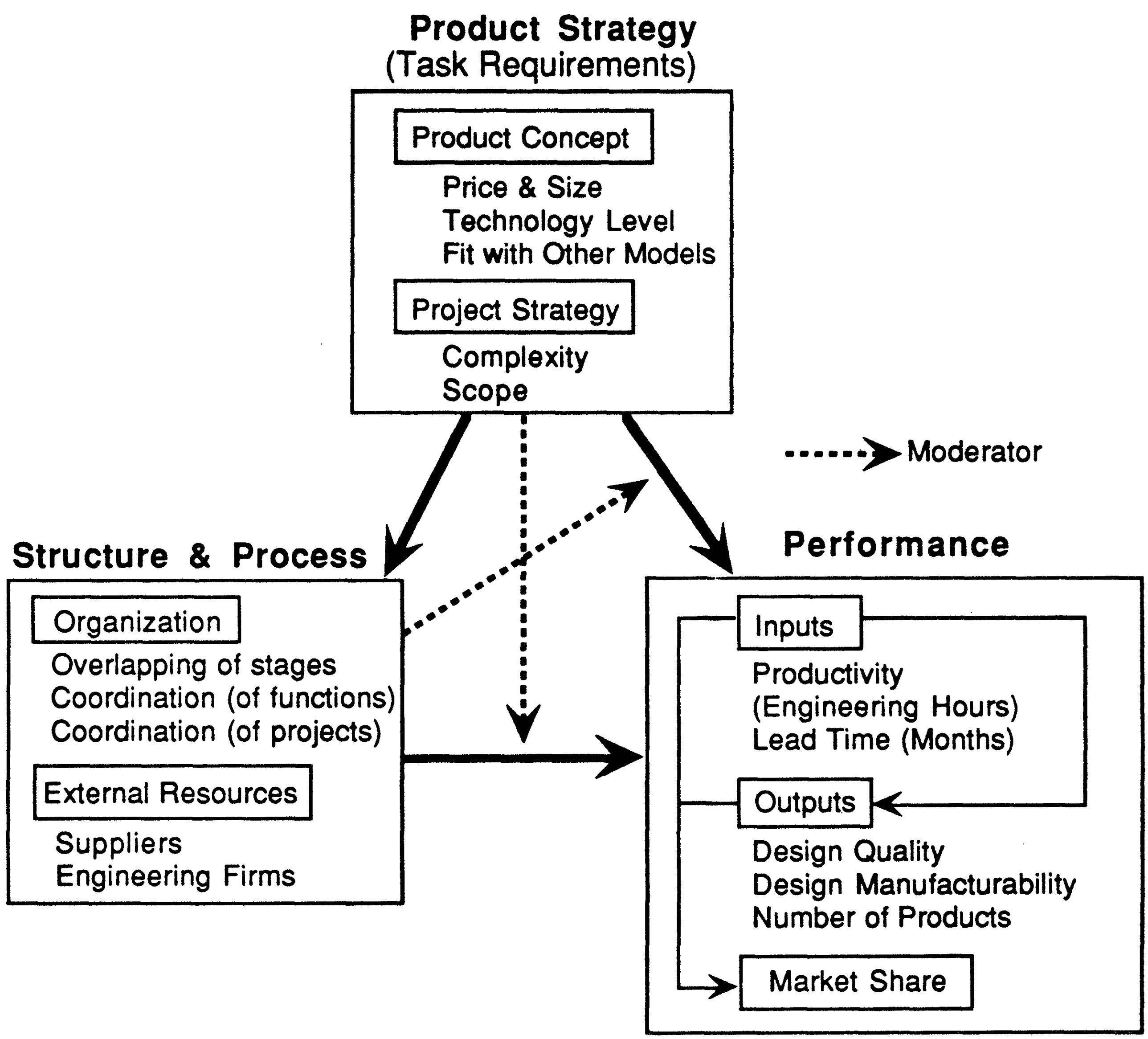
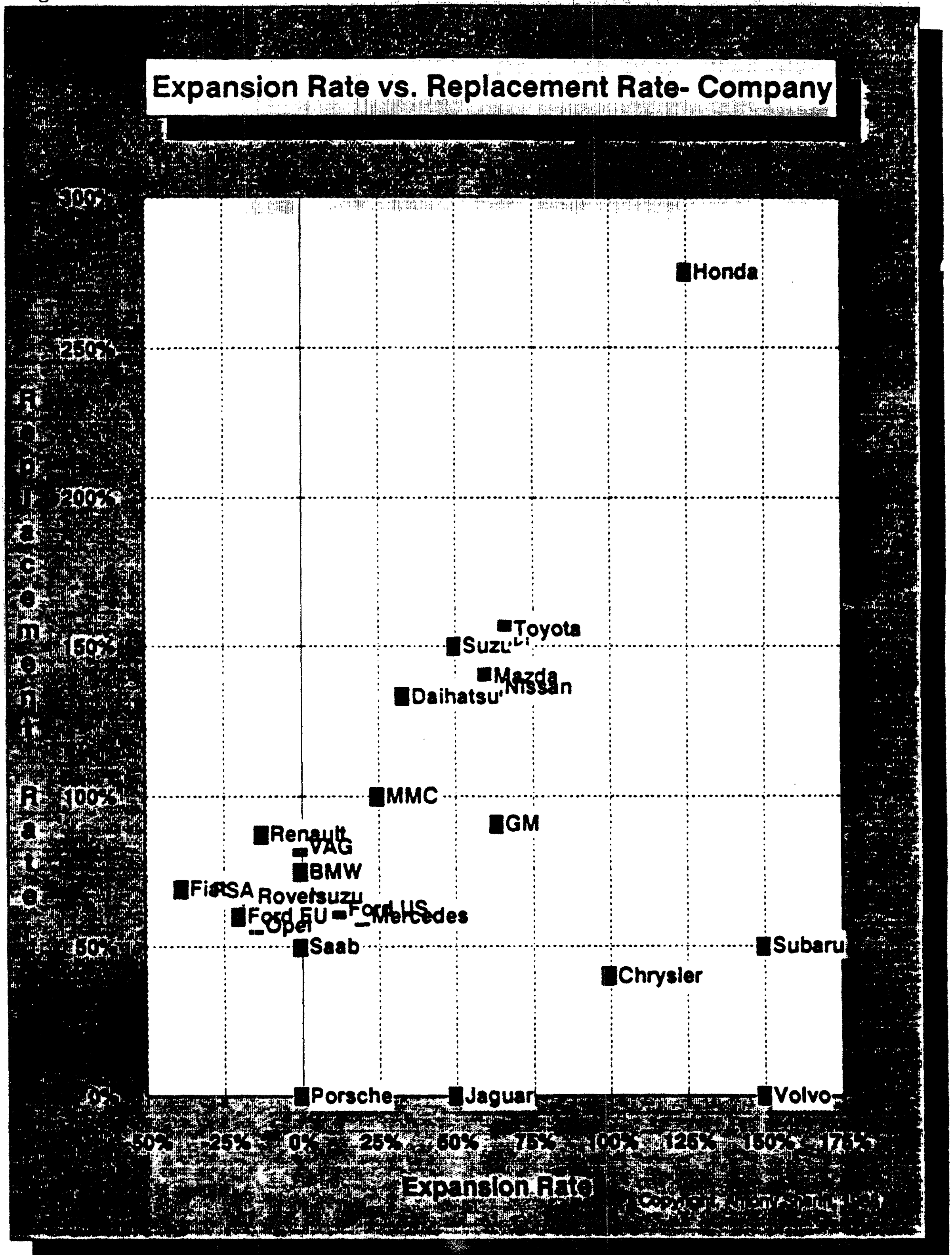
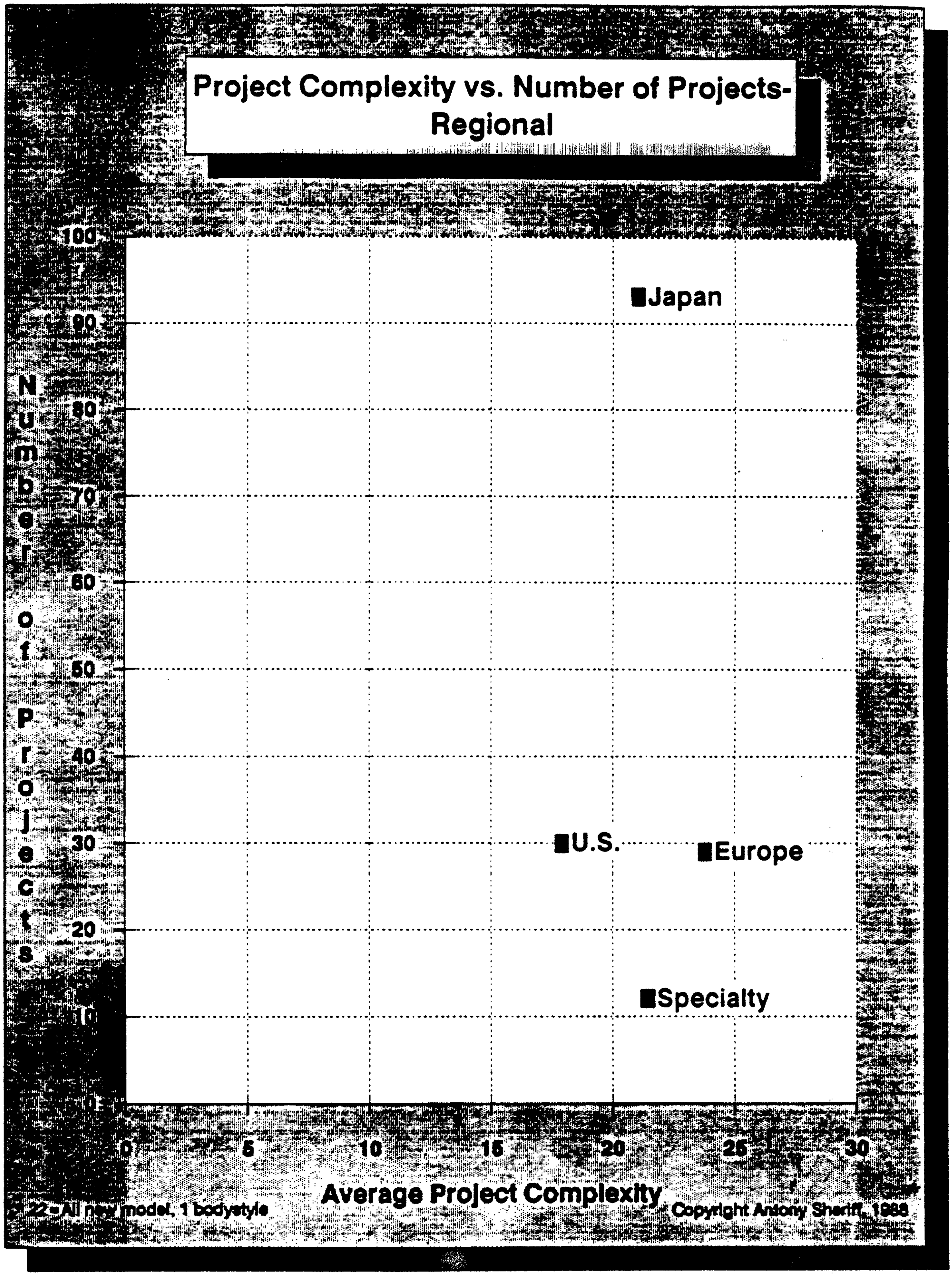


Figure 2:



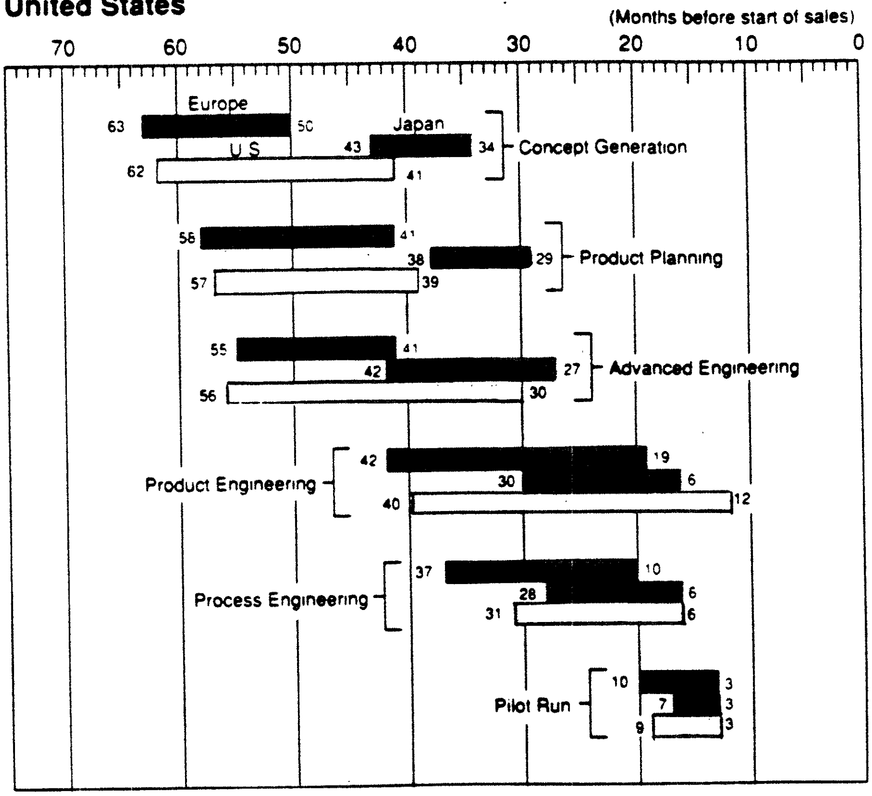
Source: [33], p. 115.

Figure 3:



Source: [33], p. 33.

Figure 4. **Development Lead Time: Europe, Japan and the United States**



Japanese averages are different from the non-Japanese averages at 5% level of significance in all of the above categories. The differences between U.S. averages and European averages are not significantly different.

Source: [8], p. 50.

Table 1. Major Automobile-Producing Country Totals

Unit: 1,000,000 Vehicles (Cars and Trucks)

	1960	1970	1980	1987
Japan	0.5	5.3	11.0	12.2
U.S.	7.9	8.3	8.0	10.9
W. Germany	2.1	3.8	3.9	4.6
France	1.4	2.8	3.4	3.5
Italy	0.6	1.9	1.6	1.9
U.K.	1.8	2.1	1.3	1.4
World	16.3	29.6	38.4	45.8

Source: [26].

Table 2. Major Firms' Automobile Production World Totals, 1970 and 1987

Unit: 1,000,000 Vehicles (Cars and Trucks)

	1970	1987	Increase (%)
Honda	0.4	1.6	400
Mazda	0.4	1.2	300
Mitsubishi	0.5	1.2	240
Toyota	1.6	3.7	231
PSA (Peugeot)	1.1	2.5	227
Nissan	1.4	2.7	193
Volkswagen	1.6	2.5	156
General Motors	5.3	7.5	142
Ford	4.9	5.9	120
Fiat	1.5	1.9	127
Renault	1.9	2.0	105
Chrysler	2.5	2.2	-12

Source: [26] and company annual reports.

Table 3. Recent Studies of Auto Product Development

Studies	Major Variables	Sub-variables	Level of Analysis
Imai et al. (1985) [17]	Structure/Process	Overlapping Coordination	Project
Clark et al. (1987) [6] Fujimoto (1989) [13] Clark (1989) [7] Clark & Fujimoto (1989) [8]	Product Strategy	Price Size Complexity Scope	Project, Region
	Structure/Process	Overlapping Coordination Suppliers	
	Performance	Productivity Lead time Design quality	
Sheriff (1988) [33] Fujimoto & Sheriff (1989) [14]	Product Strategy	Complexity Scope	Firm, Region
	Performance	No. of products Expansion rate Replacement rate Avg. product age Market share growth	
Sakakibara & Aoshima (1989) [32]	Product Strategy	Fit with other models	Project, Firm
Krafcik (1990) [22]	Performance	Manufacturability	Firm

Table 4. Clark, Chew, and Fujimoto Data Summary

variables \ strategic-regional groups	Japanese volume producer	U.S. volume producer	European volume producer	European high-end specialist	overall
number of organizaions	8	5	5	4	22
number of projects	12	6	7	4	29
year of introduction	1981-85	1984-87	1980-87	1982-86	1980-87
engineering hours (millions)	Av. 1.2 Min. 0.4 Max. 2.0	Av. 3.5 Min. 1.0 Max. 7.0	Av. 3.4 Min. 2.4 Max. 4.5	Av. 3.4 Min. 0.7 Max. 6.5	Av. 2.5 Min. 0.4 Max. 7.0
lead time (months)	Av. 42.6 Min. 35.0 Max. 51.0	Av. 61.9 Min. 50.2 Max. 77.0	Av. 57.6 Min. 46.0 Max. 70.0	Av. 71.5 Min. 57.0 Max. 97.0	Av. 54.2 Min. 35.0 Max. 97.0
retail price (PRICE) (1987 U.S. dollars)	9238	13193	12713	31981	14032
# of body types (BODY)	2.3	1.7	2.7	1.3	2.1
common parts ratio (C)	18%	38%	28%	30%	26%
ratios in parts cost					
supplier proprietary (SP)	8%	3%	10%	3%	7%
black box (BB)	62%	16%	38%	41%	44%
detail-controlled (DC)	30%	81%	52%	57%	49%
supplier engineering ratio (S = SP + BB * 0.7)	51%	14%	37%	32%	38%
vehicle size (# of project)					
micro-mini	3	0	0	0	3
subcompact	4	0	3	0	7
compact	4	1	3	1	9
mid-large	1	5	1	3	10

Note: Definitions of the variables are as follows:

Year of introduction: calendar year when the first version of model was introduced to market
Engineering hours: hours spent directly on the project (excluding process engineering)
Lead time: time elapsed between start of project (concept study) to start of sales
Retail price: average suggested retail price of major versions in each model in 1987 U.S. dollars
# of body types: number of significantly different bodies in number of doors, side silhouette, etc.
Common parts ratio: fraction of parts common to other or previous models in # of parts drawings
Supplier proprietary parts: those parts which are developed entirely by parts suppliers
Black box parts: parts whose basic engineering is done by car makers, while detail engineering is done by parts suppliers
Detail-controlled parts: those parts which are developed entirely by car producers
Supplier engineering ratio: estimated fraction of engineering hours worked by parts suppliers
Based on the interviews, it was estimated that 100% of work in supplier proprietary parts, 70% of work in black box parts and 0% of work in detail-controlled parts were done by suppliers.
Vehicle size: author's subjective classification based on industry practices

Source: [13], p. 351a.

Note: Similar versions of this table appear in [6], p. 741, and [7], p. 1251.

Table 5. Sheriff Data Summary

	Japanese	U.S.	European	Specialty
# of Firms	9	3	7	6
# of New Products, 1981-1988	94	31	30	13
New Products/ Firm	10	10	4	2
Replacement Rate (%)	135	60	70	38
Expansion Rate (%)	60	55	-23	30
# of Models as of 1987-88	73	36	47	24
Average Model Age (Years)	2.1	4.6	4.6	5.7
# of Models/Firm as of 1987-88	8	12	7	4

Source: Derived from [33].

Table 6. Ranking of Project Complexity by Company and Complexity Index

Most Complex

1. Opel
2. Ford of Europe
3. Saab
4. BMW
5. Renault
6. Subaru
7. Volkswagen
8. Mazda
9. Mitsubishi
10. Fiat
11. Toyota
12. Jaguar
13. PSA
14. Ford (U.S.)
15. Honda
16. Daihatsu
17. Isuzu
18. Volvo
19. Nissan
20. Mercedes
21. Porsche
22. Rover
23. GM
24. Chrysler

Least Complex

Determination of Complexity Index

Exterior Changes

5	Trim
10	Front and Rear 10"
20	Fenders
30	Partial "Greenhouse"
50	Full "Greenhouse"
70	Total Restyle

Interior Changes

7	Trim
20	Seats and Door Panels
20	Instrument Panel
50	Total Restyle

Platform Changes

10	Slight Revision
30	New Wheelbase
30	New Suspension
30	New Track
100	New Platform

Number of Bodystyles

20% / additional bodystyle

Number of Wheelbases

10% / additional bodystyle

Calculation

Sum the weights of the appropriate changes. Multiply the result by the number of bodystyle and wheelbase multipliers.

Source: [33], pp. 116, 118.

Table 7: Phase Comparison in Product Development

(Units: Months before start of sales)

	Europe	U.S.	Japan	
Begin	63	62	43	
End	50	41	34	CONCEPT GENERATION
Length	*13*	*21*	*9*	
Begin	58	57	38	
End	41	39	29	PRODUCT PLANNING
Length	*17*	*18*	*9*	
Begin	55	56	42	
End	41	30	27	ADVANCED ENGINEERING
Length	*14*	*26*	*15*	
Begin	42	40	30	
End	19	12	6	PRODUCT ENGINEERING
Length	*23*	*28*	*24*	
Begin	37	31	28	
End	10	6	6	PROCESS ENGINEERING
Length	*27*	*25*	*22*	
Begin	10	9	7	
End	3	3	3	PILOT RUN
Length	*7*	*6*	*4*	
Total Length	**101**	**124**	**83**	

Note: Japanese averages are different from non-Japanese averages at the 5% level of significance. The differences between U.S. and European averages are not significant.

Source: Derived from [8], p. 50.

Table 8. Design for Assembly (DFA) Rankings

Company	Average Rank	Range of Rankings	DFA Score
1. Toyota	2.2	1- 3	100.0
2. Honda	3.9	1- 8	89.7
3. Mazda	4.8	3- 6	84.4
4. Fiat	5.3	2-11	80.6
5. Nissan	5.4	4- 7	80.4
6. Ford	5.6	2- 8	79.2
7. Volkswagen	6.4	3- 9	74.3
8. Mitsubishi	6.6	2-10	73.6
9. Suzuki	8.7	5-11	60.2
10. GM	10.2	7-13	51.4
11. Hyundai	11.3	9-13	44.6
12. Renault	12.7	10-15	35.9
13. Chrysler	13.5	9-17	31.1
14. BMW	13.9	12-17	28.8
15. Volvo	13.9	10-17	28.6
16. PSA	14.0	11-16	28.0
17. Daimler-Benz	16.6	14-18	16.6
18. SAAB	16.4	13-18	13.7
19. Jaguar	18.6	17-19	0.0

Source: [22], p. 5.

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