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Multi-Project Strategy and Organizational Coordination in Automobile Product Development

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WP#3487-92/BPS
Date: November 5, 1992

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1. Introduction

Since the management of new product development has become a central issue in global competition, numerous academic researchers in recent years have undertaken studies of how effective and efficient projects have been in various industries. Most of the empirical research has focused on the innovation process and on managerial or organizational approaches as well as performance measures for individual projects (Imai et al., 1985; Henderson, 1990; Clark and Fujimoto, 1991; Cusumano, 1991). At the same time, there are various reports that leading Japanese manufacturers tend to develop new products much more frequently than U.S. or European competitors and that this has been one of the major reasons, along with manufacturing skills, for their strong growth performance in global markets (Abegglen and Stalk, 1985; Dertouzos et al., 1988; Womack et al., 1990). At the same time, even Japanese manufacturers became more concerned with efficiency. In recent years they have faced severe profitability problems related at least in part to the high costs of developing and manufacturing so many new products and product variations in markets, such as automobiles and consumer electronics, where demand has slowed or even declined, while the cost of money in Japan has increased due to rising interest rates and drops in the stock market and real estate values (Business week, 1992). An essential missing area in research on product development that relate directly to the issue of how to produce multiple products and variations more efficiently is the management of multiple new-product development efforts over time at the firm level. This is important because, while high levels of engineering productivity in individual projects may contribute to making a firm overall more efficient in product development, to develop a successful stream of new products over many years, as well as to take advantage of designs and components in more than one product without compromising the final products unnecessarily, requires some degree of planning and coordination above the level of the individual project.

In industries where manufacturers offer multiple products to the market and undertake multiple projects in parallel new product development strategies and organizations must take at least two elements into consideration. First, they need to plan for the frequency of new development projects, both to replace existing products and to expand the breadth of available product lines (Utterback and Abernathy, 1975; Miller, 1988; Kekre and Srinivasan, 1990; von Braun, 1991). This frequency becomes a central competitive dimension because some manufacturers appear to be much more prolific in their new product introductions than others. Secondly, firms need to plan how related they want products to be, such as in terms of components or design features, and manage the coordination process among multiple projects as necessary. For example, some manufacturers develop an extensive number of different products that share the same basic design, while others prefer to use unique designs more often in each of their different new products (Clark and Fujimoto, 1991; Womack et al. 1990). These differences may reflect decisions made above the project level, yet they affect not only the project organizations but also a firm's competitiveness. Nonetheless, there has been little empirical research that explores the interrelationship of these factors and their impact on either market or organizational performance.

Numerous studies in recent years have examined differences in strategy, structure and performance for new product development among worldwide auto manufacturers (see Cusumano and Nobeoka 1992 for a detailed review of this literature). In particular, Clark and Fujimoto at Harvard University and the International Motor Vehicle Program at MIT have found several important differences in management and performance among Japanese, U.S. and European manufacturers (Clark et al., 1987; Sheriff, 1988; Womack et al., 1990; Clark and Fujimoto, 1991). Clark and Fujimoto conducted the most thorough study, focusing on 29 projects from 22 producers. They concluded that the Japanese firms, in general, were better at new product development as measured by design quality, lead time, and productivity defined by engineering hours. Among volume producers, three factors also contributed to better project performance: heavier project manager responsibility, higher supplier involvement in engineering, and more overlapping between stages such as product planning, product engineering, and process engineering. Clark elaborated on these data in a 1989 paper that focused on the result showing that Japanese projects used more unique parts than U.S. or European firms, which theoretically may increase design quality but also add time and cost in development, unless fitting old parts into new designs creates additional coordination that increases engineering time (Clark, 1989). He concluded that Japanese projects had more unique parts and higher engineering productivity than their U.S. and European counterparts primarily because they made more extensive use of suppliers. Since Clark and Fujimoto's sample consisted of one or two projects from each firm, they limited their study to a project-level analysis and comparisons, with statistical analysis, of regional averages for Japanese, European, and U.S. producers. Therefore, it is difficult from this sample to generalize about the linkage between project-level performance and firm-level performance in the marketplace. Nor were they able to explore the potential impact of different inter-project strategies and management approaches on organizational and market performance.

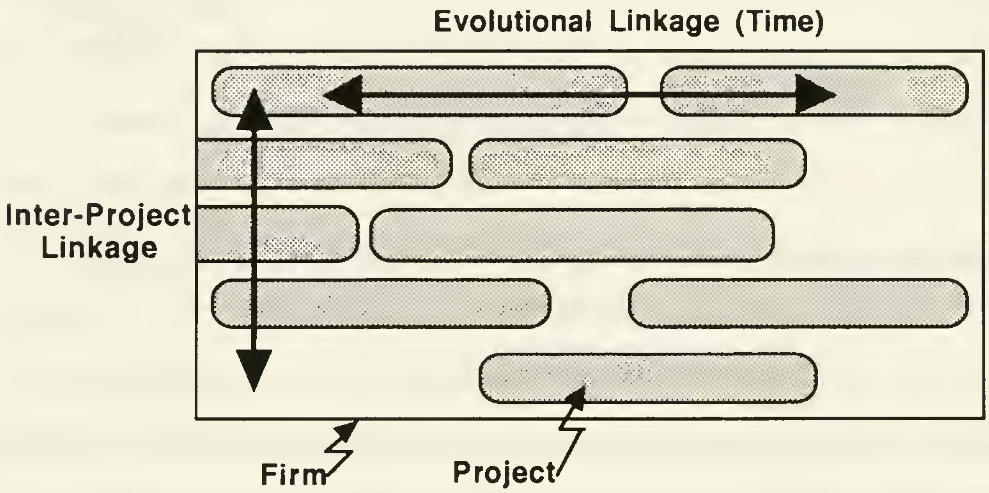
As part of the MIT study, Sheriff measured differences in the frequency of new product introductions and average project complexity for 25 major auto manufacturers between 1982 and 1987 (Sheriff, 1988; also reported in Womack et al., 1990). Project complexity was calculated through an index that assigned weights to changes made in major exterior, interior, and platform components, with adjustments upward for each additional body style or wheelbase variation. These data confirmed that Japanese firms introduced new products much more frequently than U.S. or European firms. As a result, the Japanese firms maintained much newer products in the market and increased the number of product offerings during this period. In addition, Sheriff's measurements showed that the European projects had the highest average complexity, followed by the Japanese and then the U.S. producers. Fujimoto and Sheriff then compared their data to explore interrelationships and found positive correlations between productivity measures such as lead time as well as engineering hours at the project level and the performance variables at the firm level (Fujimoto and Sheriff, 1989). They also found a positive correlation between the rate of new product introductions and market-share growth, although this paper did not explore the impact of project complexity on market performance.

The purpose of our study is to build on this research and explore product-development strategy and organization for multiple projects within the firm. The underlying hypotheses are that, apart from differences in organizational performance for individual projects, differences in inter-project strategy and management should significantly influence how efficient and effective an entire firm is in new product development, and this effectively should have an impact at least on market share or sales growth if a firm introduces more and newer products into the marketplace than competitors. Specifically, this paper examines two questions. First, we propose a typology of product development projects based on inter-project linkages to discuss an effective multi-project strategy in the market. In this section, we argue that managing concurrent interactions effectively between multiple projects within the firm may create competitive advantage in the market, because in this way firms can transfer technology and design quickly across multiple projects and can effectively leverage their engineering and financial resources. We investigated this question by analyzing 223 new car products introduced at 21 automobile manufacturers between 1980 and 1990. Secondly, we discuss the organizational coordination required to manage interactions between concurrent multiple projects within firm based on a questionnaire survey of 225 engineers at six automobile firms in Japan and three in the U.S.

2. Firm-Level New Product Management and Research Questions

Large automobile manufacturers have several product lines and constantly develop new products to replace existing products or to add new product lines over time as shown in Figure 1. Each project within a firm has some linkages with other projects both technologically and organizationally. Managing the way different projects interact organizationally or relate to each other technically is by no means a simple matter. Consideration of multi-project management includes both linkages between different product lines and linkages between past and present projects. For example, some projects use the basic design framework of their previous models and others use designs from other product lines, while some projects may choose to develop a new technology and design from scratch. A different way of interaction a project chooses with other projects may have different influence on the new product competitiveness and may impose different requirements on the project management. In addition, because managing the inter-project linkages effectively may require an extensive integration across a firm, the patterns firms choose regarding inter-project linkages may have an influence on their organizational competitiveness as a whole. In order to simplify the complicated multi-project strategy and management at the firm level, the next section proposes an analytical framework by decomposing the multi-project patterns into four different types of inter-project relations.

Figure 1. Dimensions of Multi-project Management

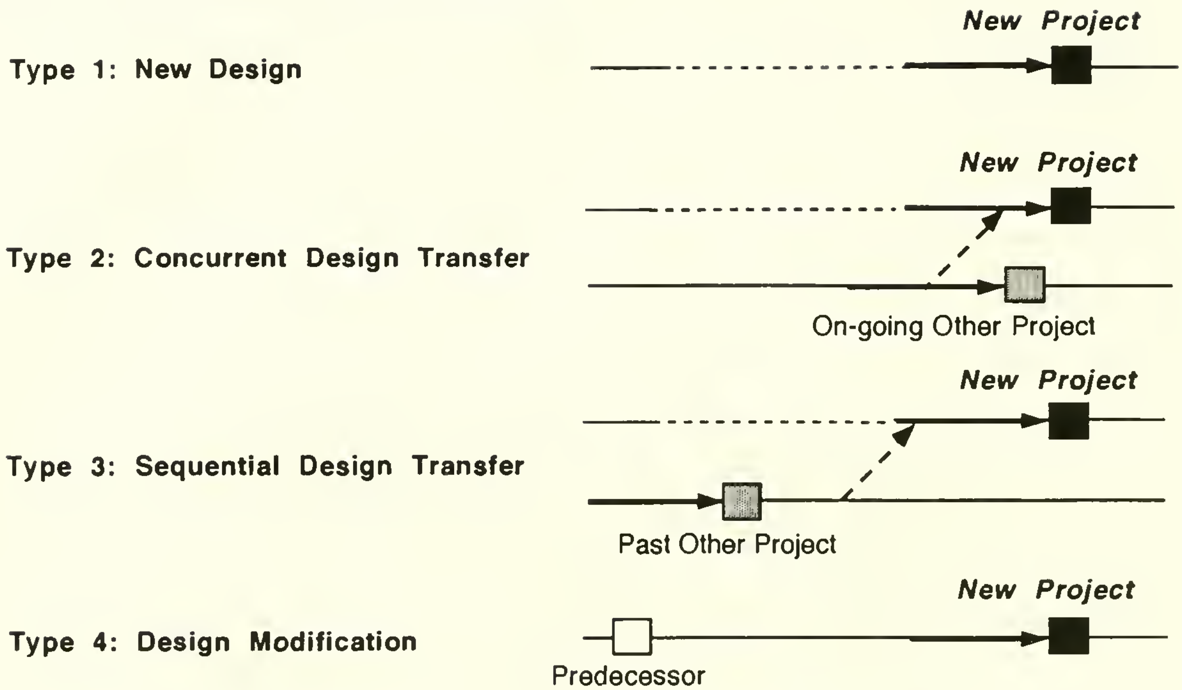


3. Influence of the Inter-project Strategy

3-1 Typology of Inter-Project Strategy and Design Age

Firms have various alternatives for inter-project strategies used in new product development. Figure 2, which presents a typology of these strategies, categorizes new product development projects into four types, depending on two dimensions: the extent of changes and sources of the base design. The extent of change differentiates a new project whether its core design is newly developed or transferred and modified from other projects within the firm. Projects that develop their own new core designs are categorized as a new design. In the latter case, variations of the modification can be broken down into three types, depending on the location of base design sources: either an on-going other project, an existing other product, or the new project's predecessor product. These three types are labeled here as concurrent design transfer, sequential design transfer, and design modification, respectively.

Figure 2. Typology of the Inter-project Strategy



The first type, *New design*, thus refers to the development of a new product with a core design produced primarily from scratch, without a preexisting base design. In this type of project, there is little relatedness or interaction with any other projects within the firm. Members of the project can concentrate on creating a new design and a new product. While the project's engineering task requirements should be high because the design is new (Clark, 1989), both coordination costs and design constraints are low because the project does not have to be coordinated with other projects or follow design constraints derived from an existing design base.

The next two types of projects transfer and share a core design from other projects within the firm. In the second type, *concurrent design transfer*, a new project begins to transfer a core design from a base project before the base project completes its design engineering. These two projects -- the new project and the base project -- require extensive and potentially costly coordination because (1) they must overlap chronologically, (2) the new project needs to incorporate a design from the base project while the design is still under development or relatively new, and thus (3) mutual adjustments in design between the two projects are still possible and perhaps likely.

The third type, *sequential design transfer*, transfers a design from a base model after the base model's development is finished. Because this type of project basically reuses an existing design that is "off-the-shelf," inter-project coordination is not needed. When a new project uses the core design in this manner, however, the design being transferred is already relatively old, compared to designs transferred more concurrently. In addition, design constraints may be high because mutual adjustments between projects on the core design are no longer possible.[1]

The last type, *design modification*, refers to a new development project that modifies a direct predecessor product as in a relatively minor model change. This type of project does not need any inter-project coordination either, but has to consider constraints from the core design of the current model. The difference between the design modification and the sequential design transfer is thus the source of the base design. Modifications in this type may be easier than with a sequential design transfer, which transfers a core design between different product lines. Another difference is that sequential design transfer can be used to add a new product line, while a design modification is only for replacement projects.

One of the strong points of this typology scheme is that it determines design age of each strategy type, which is the age of the core design a new project uses. Design age is determined by the difference in time between the introduction of the new product and when the original design on which the product was based was first introduced. For example, design age of a new product utilizing transfer strategies is the time that has passed since the base product was introduced to the market. Thus, design age of a new project using the concurrent design transfer is smaller than that of the sequential design transfer. Design age of a new project that develops a core design from scratch using the new design strategy is the smallest, zero. Design age of a new product using the

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[1]. This discussion of hypothetical differences between concurrent and sequential design transfer are partially based on Thompson's distinction between "long-linked technology" and "intensive technology," where the latter also requires mutual adjustments and higher coordination costs. See Thompson, 1967

design modification strategy is the same as the product life cycle of its predecessor model, which can even be older than with a sequential design transfer.

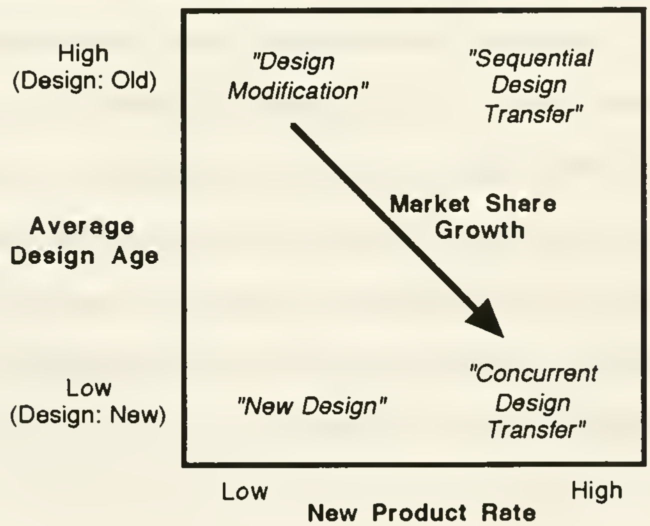
3-2. New Product Rate, Average Design Age, and Different Types of Inter-project Strategy

The new product rate here is defined as a ratio of the number of new product introductions adjusted by the number of product offerings in a base year. A higher new product rate makes it possible for a firm to replace existing products or enter new market segments more frequently than competitors (Miller, 1988; Fujimoto and Sheriff, 1989; Kekre and Srinivasan, 1990). In order to increase the new product rate, firms need to invest more financial and engineering resources. Otherwise, frequent new-product introductions may reflect incomplete development efforts and result in products that suffer from problems in design quality and perform poorly in the market. If firms do not want to or cannot increase their resource investments, then increasing the new product rate requires a decrease in task requirements, because as Clark (1989) illustrated, a project that develops more new components generally requires more lead time and engineering hours. Thus, it may not be a reasonable choice for a firm that pursues a high new product rate to utilize the new design strategy, extensively.

Firms have at least two choices to decrease engineering tasks for new components: decrease the average intra-project variations such as the number of body and styling types, or repeat the same design among different new projects. Decreasing intra-project variations may have a negative impact on market competitiveness if products appear too similar to consumers and lead to a reduced coverage of market segments. The repeated use of the same design or components may also have a negative impact on market competitiveness, because the purpose of frequent new product introductions is to capture changes in customer needs with new technology, and reuse of an old design may conflict with this objective. However, the rapid reuse among multiple projects of new technology may actually improve the overall newness or technological sophistication of a firm's product offerings. Therefore, we can hypothesize that the negative impact on a firm's market competitiveness should depend to some extent on the average design age of new products introduced into the marketplace. There should generally be a tradeoff between increasing the new product rate and incorporating new designs into each new product, rather than extensively reusing the same design. Successful automobile firms regarding market share growth may develop more new products without introducing older designs than their counterparts. One of Clark's findings, for example, implied that, in order to avoid this tradeoff, some of the successful Japanese manufacturers depended more on outside suppliers for new component designs (Clark, 1989). Our study explores the idea that successful manufacturers may also have different inter-project strategies from low performing manufacturers in order to mitigate this tradeoff.

Figure 3 shows hypotheses regarding the influence of different inter-project types on design age and new product rate. An extensive usage of the transfer strategies, concurrent design transfer or sequential design transfer, may provide firms with an advantage in developing more new products than the other two project types, because same technology or design is shared by multiple projects. A new product using sequential design transfer necessarily incorporates older technologies in the product than those using concurrent design transfer. Therefore, in order to both increase new product rate and keep average design age low, a firm may choose to use concurrent design transfer strategy. An extensive use of new design strategy may end up with a low average design age but may have a negative impact on the new product rate.

Figure 3. Hypotheses on Inter-project Types



3-3. Sample Characteristics and Measurements

The sample in this study covers the 21 largest auto manufacturers in the world, including seven Japanese, three U.S., and eleven European producers, and the 223 new car products they introduced between 1980 and 1990. Data on new product development in the industry were primarily collected from Auto Review, an annually published industry journal that covers design features and introduction dates for all new products worldwide. Unstructured interviews with engineers in these firms were also conducted when needed for clarification. We used the cumulative worldwide market (unit-production) share growth of each manufacturer during this period to categorize firms into three groups: high performers, middle performers, and low performers.

Inter-Project Strategy and Average Design Age

As a firm-level analysis of inter-project strategies, we classified new car projects done within individual firms during 1980-1990 into four inter-project strategy types. By identifying a new car project's inter-project type and its base model, its design age is determined as defined earlier. We measured the new product rate for each manufacturer by the ratio of the number of new product introductions between 1980 and 1990 divided by the number of product offerings in 1979. We defined a new product as a model designed within a single project and with completely new interior and exterior stylings. By this definition, a new product with minor cosmetic modifications is not counted as a new product. Product variations designed within a single project, such as the Ford Taurus and Mercury Sable, count as only one new product. On the other hand, we used another variable for intra-project variation to show the average number of different body types and stylings developed within individual projects. Whether two or more new variations were in fact developed together within one project or separate projects is critical to this study, because this affects the total number of new projects and the nature of their interrelationships. Most cases, such as the Taurus and Sable, are openly discussed in Auto Review or other industry journals. For unclear cases we have had to rely on interviews with company engineers.

The core design used in the present data analysis is the platform design, which determines the basic characteristics of other major component designs, including the body and engine size, drive-train type, and the general level of design sophistication. Designing a new platform from scratch requires both financial and engineering resources as well as new technology. In order to determine whether the platform of a certain new project was newly developed or transferred from preceding products, we assigned points to the extent of changes in platform design between the new product and preceding products similar to the new product, based on changes in the wheelbase and tread as well as the suspension design (see Appendix 1 for more details).

New projects that developed new platform designs are automatically categorized as the first type, new design, while those developing new products based on platforms from other projects fall into one of the other three categories. Design age in this type is zero as defined earlier, while in the other three types, design age is measured by the difference in time between the introduction of the new product and when the base product was first developed. Projects that developed a new product based on the platform design of the predecessor model are categorized as design modifications, while those which shared platform designs with any preceding projects are either concurrent design transfers or sequential design transfers. As indicated earlier, the distinction between concurrent and sequential transfers is determined by the transfer time lag, which is the same as the design age defined above.

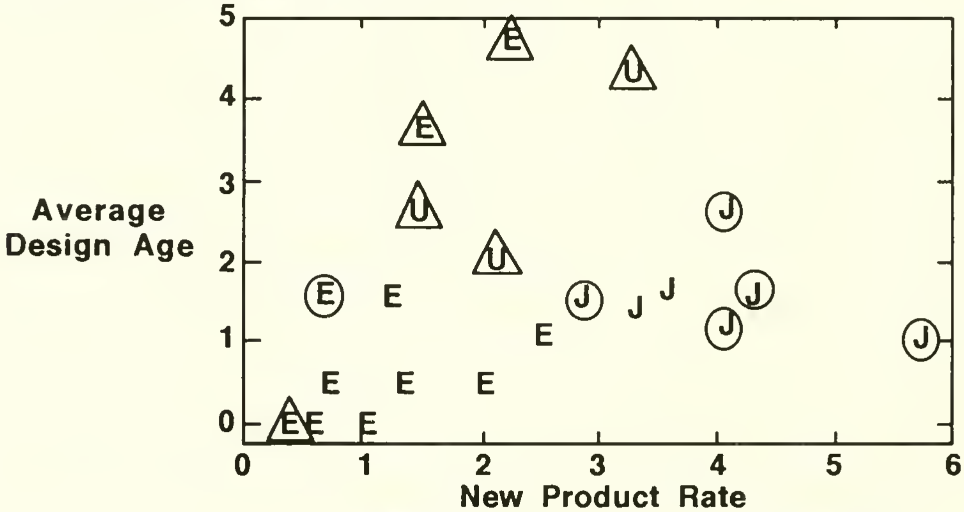
First, we compared the average transfer time lags for the Japanese, U.S., and European projects that were not new designs or modifications. We then defined concurrent design transfers as a transfer between two projects occurring within 2.0 years of the introduction of the core design. Visual analysis of a frequency distribution for new projects indicated that one group of projects transferred designs within 1.25 years, while another group transferred most designs after 2.25 years (Appendix 2). The figure 2.0 years was also the median transfer lag time for the entire sample and is close to the midway point (2.25 years) for the average lead time (4.52 years) for new car development as calculated by Clark and Fujimoto (1991: 73). We also tested the sensitivity of this division by using 1.5 years and 2.5 years as cutoff points, with no significant change in the results.

In addition, we believe that if the time lag is longer than two years, then there does not need to be much overlapping or coordination between projects.

3-4. Results and Discussion

Firms in the high new product rate/small average design age region tend to have gained more market share than the others as shown in Figure 4. Low performers including all three U.S. firms and two European firms developed fewer products with older designs than most of high performers. Middle performers dominated by European firms tended to develop fewer products with newer designs. Figure 4 also suggests that European and U.S. firms, but not Japanese firms, experienced a tradeoff between the new product rate and average design age.

Figure 4. New Product Rate and Average Design Age



(J: Japanese firms, U: U.S. firms, E: European firms)

○ : High performers -- Market share increase by 35% or higher

△ : Low performers -- Market share decrease

Table 1 summarizes differences in usage of different inter-project strategy types between 1980 and 1990. Three different patterns are evident in each group. Most importantly, high performers utilized concurrent transfer strategy more than the other firms, which, we believe, contributed to both higher new product rates and relatively new average design ages. In other words, instead of developing many completely new core designs to achieve these two key objectives, high performing firms created a few new core designs and quickly transferred these to other product lines, while the designs were still relatively new. Since 23% of new projects at these firms used concurrent design transfer, at least 46% of their projects may have required extensive inter-project coordination because each concurrent transfer involves some overlapping with at least one other project from which the core design is transferred.

Table 1. Comparison between U.S., European, and Japanese Manufacturers

	High Performer	Middle Performer	Low Performer
Number of Manufacturers	6	9	6
Number of New Projects	84	78	61
Inter Project Strategy (%)			
New Design*	.44 (.09)	.69 (.07)	.49 (.09)
Concurrent Design Transfer**	.23 (.05)	.09 (.04)	.05 (.04)
Sequential Design Transfer**	.16 (.08)	.16 (.06)	.29 (.08)
Design Modification	.17 (.06)	.06 (.05)	.18 (.06)
New Product Rate**	3.58 (.52)	1.78 (.42)	1.81 (.52)
Average Design Age***	1.62 (.43)	0.81 (.35)	3.00 (.43)
Average Intra-project Variations	2.09 (.19)	1.89 (.16)	2.14 (.19)
Market Share Growth***	.78 (.11)	.15 (.09)	-.24 (.11)

(Standard deviations are in parentheses)
Statistically Significant at: *** 1% Level, ** 5% Level, * 10% Level (One-way ANOVA)

The middle performing firms between 1980 and 1990, mostly European makers, are characterized by an extensive use of completely new designs, which explains the low average design age of their new products. Even though they developed fewer new products, by concentrating on these products, they developed newer designs than other producers. Low performing makers tended to have more sequential design transfers than other firms, which resulted in older designs in their new products. Accordingly, they did not develop either as many products as high performers or as many new designs as middle performers. These is no significant difference in average intra-project variations, which suggest that increasing the complexity of each project by adding variations in styling and body types did not have a significant impact on market share.

We realize that variables here are too limited to predict market performance. Sales growth, for example, ultimately should result from the ability of a firm to design and build products that customers want to buy, and this relates to quality, price-performance, advertising, product availability, service, and other factors. Our primary intention here is to propose a conceptual framework on inter-project strategy and to show that high performing firms seem to adopt a different product-development strategy that also has specific organizational implications. Specifically, high performing firms seem to transfer new designs among multiple projects quickly, which contributed to both higher new product rates and relatively new average design ages. We also assumed that in order to implement concurrent design transfer, two or more different projects have to coordinate with each other. In the next section, we examine organizational requirements to manage concurrent inter-project interactions.

4. Organizational Requirements for Managing Inter-project Interactions

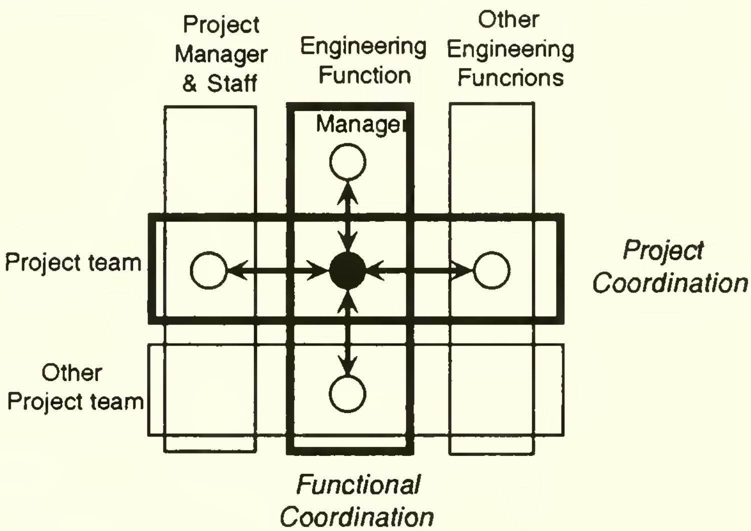
4-1. "Project Coordination" and "Functional Coordination"

One of the central issues in managing a new product development organization for a complicated product such as an automobile that consists of many different components and functions is coordination among different groups within the organization. There have been numerous studies that focused on importance of coordination in a new product development organization, although few study explored the influence of inter-project interactions on coordination requirements (Allen, 1977; Tushman, 1978; Galbraith, 1982; Clark and Fujimoto, 1991). This section, we start with discussing conceptual frameworks and empirical findings from past studies, even though they do not consider inter-project interactions, because they are necessary as a basis for our later discussions regarding the influence of the inter-project interactions.

Product development organizations for a complicated product basically have two major goals: One is to manage the organizational inputs of technical knowledge and the other is to manage organizational outputs of designs for new products. In order to increase the quality and quantity of inputs of technical knowledge, a high degree of coordination around technical specialties including component as well as functions such as design and manufacturing is needed. On the other hand, in order to integrate all inputs toward well-defined outputs effectively, a high degree of coordination within and around a project is needed (Marquis, 1965; Galbraith, 1974; Katz, 1985). Managing each of these two types of coordination and the balance between them are central issues in managing product development.

New product development organizations at large automobile firms appear to be a matrix organization to take care of these two types of coordination (Clark and Fujimoto, 1991). Figure 5 shows a simplified model of such a matrix product development organization, positioning design engineers in an engineering function at the center of the matrix. Design engineers work both for a functional manager primarily regarding technical or component issues and for a project manager regarding the integration of inputs and intermediate outputs into final products. In addition, many engineers formally or informally interact with engineers in other functions who work for the same new product project to integrate technical outputs across functional areas. Furthermore, they may also want to maintain a close working relationship with engineers in the same technical discipline, including those who work for other projects, to update and refine "state-of-the-art" technologies. "Other engineering functions" in Figure 5 consist of design engineers of other components and manufacturing engineers. In this framework, project coordination is defined as the degree of coordination between engineers and a project manager and her staff as well as engineers in other engineering functions. Functional coordination refers to the degree of coordination between engineers and a functional manager as well as engineers in their same technical function who work for other project teams.

Figure 5. Matrix Product Development Organization and Definition of "Project Coordination" and "Functional Coordination"



Using a similar conceptual framework in their study of automobile product development, Clark and Fujimoto (1991) argued that among volume producers heavier project manager responsibility and closer coordination between different engineering functions positively influence project performance in lead time, productivity, and design quality. In other words, a strong project coordination led by a strong project manager is necessary for good project performance. There also have been numerous studies in other industries on the importance of both intra-project and functional coordination, which primarily discuss advantages and disadvantages of project and functional organizations as well as of matrix organizations. For example, Marquis and Straight (1965), by investigating thirty eight R&D projects under contract with a government agency, conducted the first extensive study regarding this issue. Using two dimensions - the authority and autonomy of the project manager, and the form of organizational reporting relations - they categorized the form of project organizational structure into project, functional, and matrix organizations. They concluded that functional organizations tend to be more effective in technical performance, while project organizations tend to be more successful in cost and lead time. Larson and Gobeli (1988) conducted a mailed questionnaire survey for 540 development projects in a variety of industries including pharmaceutical, aerospace, and computer in both Canada and the United States. They found that in all schedule, cost and technical performances, project-oriented teams tend to be more successful than function-oriented organizations. Katz and Allen (1985) studied eighty-six R&D projects in nine major U.S. organizations to examine the relationship between project performance and the relative influence of project and functional managers. They concluded that performance reaches its highest level when organizational influence is centered in the project manager and influence over technical details of the work is centered in the functional manager.

In these empirical studies, project-oriented structures, rather than function-oriented structures, resulted in higher performance, especially in cost and schedule, while in some cases functional orientation was appropriate for technical performance. However, no study has explicitly treated questions of inter-project interactions in design or engineering either conceptually or empirically. Yet, it is important to study the influence of inter-project interactions on organizational requirements, because as discussed in the first part of this paper, an effective management of the inter-project interactions can allow firms to leverage their engineering resources by facilitating quick transfer of new technology across multiple products. In addition, because inter-project interactions impose a new dimension of contingency on product development organizations, the findings and frameworks of past studies may have to be modified. In the next section, we discuss the potential influence of inter-project interactions on organizational requirements for project and functional coordinations in new product development organizations.

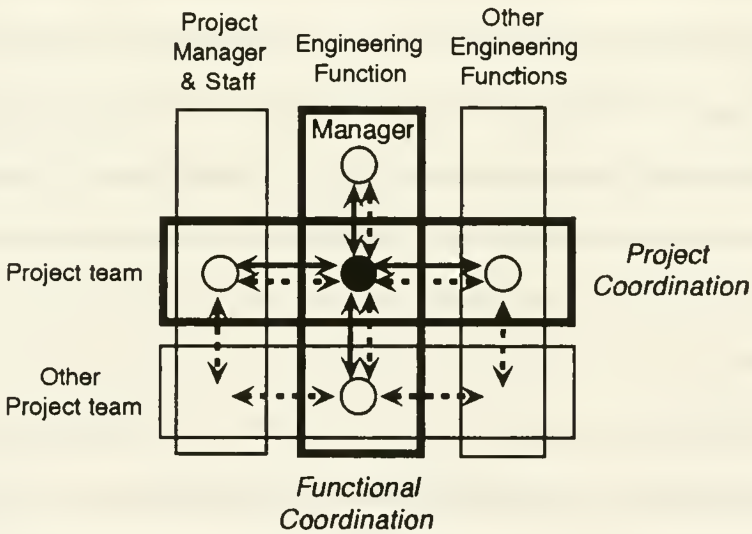
4-2. Hypotheses: Inter-project Interactions, Organizational Coordination, and Performance

Based on the past studies discussed above, we hypothesize that, *without* inter-project interactions, project coordination may have a particularly strong positive influence on operational performance such as cost and schedule. In addition, functional coordination may be as important as project coordination regarding technical performance. On the other hand, the model in Figure 6 shows possible influences of inter-project interactions on the degree of organizational coordination, which are indicated by the dotted lines. In this model, an engineer in the new product project develops a design in conjunction with an other project, in which the engineer is not directly involved.

In this case, it is assumed that there is an interdependency to some extent between these two projects regarding at least this particular component design. Requirements for the component design may not be the same between these two projects. Therefore, some coordination between engineers in these two different projects may be needed for the projects and the products to be successful. This coordination may also have to be well managed by the functional manager. In other words, the degree of functional coordination may have a stronger influence on project and product performance in this kind of design work than in a project without any inter-project interactions.

In addition to this direct requirement for the functional coordination between engineers in the two projects, requirements for intra-project coordination may also be higher than in projects without inter-project interactions. A product development project is a system consisting of closely coupled multiple engineering functions (Rosenberg, 1982). Uncertainty in part of the system increases requirements of coordination as a project (Rosenberg, 1982; Tushman, 1979). In this case, uncertainty in the engineer's task is higher than that in a project without inter-project interactions, because of the interdependency with the other project. For example, suppose there is a design change caused by interdependency between the two projects. The change must be incorporated into a final project, which may require coordination within the project. Therefore, we hypothesize that in a component design that has interactions with another project, the influence of the project coordination on design performance is also stronger than in projects without inter-project interactions. Therefore, requirements for both project coordination and functional coordination around the engineers may be significantly higher in projects with inter-project interactions than in those without inter-project interactions.

Figure 6. Influence of Inter-project Interactions on the Degree of Coordination Requirements



4-3. Sample and Measures

We conducted a questionnaire survey of design engineers at six Japanese and three U.S. auto manufacturers. 220 questionnaires were sent to Japanese firms and 90 questionnaires to the U.S. firms, and 193 (return rate; 88%) and 32 (return rate; 36%) were returned, respectively, which resulted in a total sample of 225 responses. Questionnaires were distributed by contacts in each company to engineers in as many different design functions as possible within a firm. The low return rate for the U.S. firms may have resulted from the U.S. firms' reluctance to give us data of poor-implemented projects, which we noticed in the discussion with them. However, because the purpose of this study is not a comparison of performances between the U.S. and Japanese firms, we believe that this doesn't affect the theoretical discussion in this research.

In the questionnaire, each respondent chose one specific component that he or she worked on for a specific product development project, rather than basic research or components for general use. One of the questions asked whether there was at least one other product development project that was using similar component technology or designs in conjunction with the project for which the respondent worked. Respondents were asked to think only about other projects in which they were not directly involved. Among 225 component developments, 106 appeared to have at least one other project with which they had inter-project interactions. Time difference between the two interacting projects in these responses ranged from zero to 28 months and the mean was 9.6 months. 13 of the 32 U.S. component developments and 93 out of 193 Japanese component developments are categorized as those with inter-project interactions. In the following sections, we analyze data separating these two sample groups to explore how organizational requirements differ between these two component development types.

Performance Measurements

The questionnaire asked respondents to rate on a 7-point Likert-type scale whether each component development performed above or below their expectation in schedule, cost, design quality, and the degree of match with customer needs. Cost and schedule performance data were averaged to measure the operational performance (principal component loading = 0.83). Performance ratings of design quality and the degree of match with customer needs were averaged to measure design quality performance (principal component loading = 0.87).

Measurements of the Degree of Project and Functional Coordination

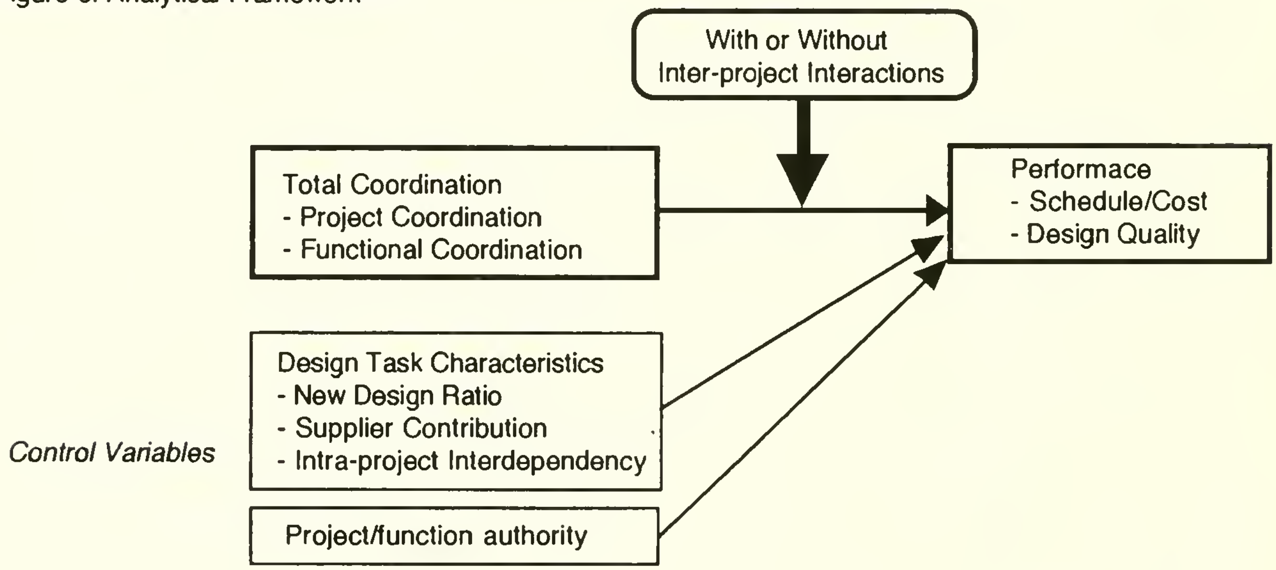
There is not a single best measurement of the degree of coordination. The degree of coordination among different groups, rather than specific means of coordination, needs to be focused in this particular analysis. The degree of communication has often been used in the past studies to measure coordination (Allen, 1977; Tushman, 1978). However, the degree of communication is not a good measure of the degree of coordination, when communication is needed to solve problems or conflicts. The degree of goal sharing among different groups could be an alternative, as Lawrence and Lorsch (1967) used as a measurement of the degree of integration. This is not a good measurement in this study, either, because all groups in a response are in a specific new product development project and there may not be enough variations in their goals. Thus, in this study, the degree of satisfaction in working relationship on a particular engineering task that each respondent chose was used as a proxy for the degree of coordination between different groups. Respondents rated the satisfactory level of working relationship regarding a specific component development with people in different groups: a functional manager, a project manager, product engineers in other functions, and manufacturing engineers, as well as engineers in their same technical function working for other product projects.

First, ratings regarding product engineers in other functions and manufacturing engineers were averaged to measure the degree of coordination with engineers in other functions (principal component loading = 0.86). Secondly, as indicated in the model shown in Figures 5 and 6, the degree of project coordination and functional coordination were calculated. The degrees of coordination with a project manager and with engineers in other functions were averaged into the project coordination (principal component loading = 0.86), while the degrees of coordination with a functional manager and with other engineers in the same function were averaged to obtain the functional coordination (principal component loading = 0.83). In addition, we also measured total coordination by averaging the degrees of project coordination and functional coordination (principal component loading = 0.96).

Control Variables

Other project characteristic variables that may affect the relationship between component development performance and organizational coordination are measured as control variables. First, the percentage of the component design that was newly designed was asked regarding *each* new component development. On average, 80% of design in the component developments with inter-project interactions were newly designed, and 87% of design were new in projects without inter-project interactions. Secondly, the percentage of design that suppliers engineered was also measured for each component design; 33% of design was done by suppliers on average in component designs with inter-project interactions and 34% in those without the interactions. Thirdly, a component's interdependency with other parts of products were measured by asking, on a 7-point Likert-type scale, the extent the component design affects the other part of the product. Lastly, respondents were asked to rate the extent of authority regarding design work that the project manager has as opposed to the functional manager. Figure 6 summarizes the analytical framework that has been explained for this research.

Figure 6. Analytical Framework



4-4. Results and Discussion

Descriptive data and a correlation matrix are shown in Table 2 for component developments with (top half) and those without (bottom half) inter-project interactions. Performance variables, in general, are correlated more strongly with the coordination variables in component developments with inter-project interactions than those without the interactions. Specifically, in component developments with inter-project interactions, both measurements of performance are correlated with both project and functional coordination. On the other hand, in those without inter-project interactions, schedule/cost performance is significantly correlated with only project coordination, while design quality is significantly correlated with only functional coordination. Organizational coordination is rated higher in component design without inter-project interactions, which indicates that achieving a strong coordination is generally more difficult in component design with inter-project interactions.

Table 2. Descriptive Data and Correlation Matrix

With Inter-project Interactions (N=106)

	Mean§	S.D.	1	2	3	4	5	6	7	8
1 Performance (Sched./cost)	3.42	.95								
2 Performance (Design Quality)	4.38	1.00	.40 ***							
3 Total Coordination	4.37**	1.01	.41 ***	.37 ***						
4 Project Coordination	4.30**	1.06	.40 ***	.32 ***	.90 ***					
5 Functional Coordination	4.44**	1.17	.34 ***	.34 ***	.92 ***	.65 ***				
6 Project Mgr Authority	.28*	.25	.18 *	.21 **	.05	.13	-.03			
7 Component's Interdependency	4.79	1.72	-.04	.22 **	.27 ***	.34 ***	.16 *	.11		
8 New Design Ratio	.80**	.28	.04	.03	.04	.05	.02	.01	.10	
9 Supplier's Design Contribution	.34	.24	-.16	-.10	.06	.01	.10	.14	-.06	-.02

Without Inter-project Interactions (N=119)

	Mean§	S.D.	1	2	3	4	5	6	7	8
1 Performance (Sched./cost)	3.62	1.14								
2 Performance (Design Quality)	4.57	1.05	.43 ***							
3 Total Coordination	4.71**	0.95	.21 **	.24 **						
4 Project Coordination	4.66**	1.06	.24 ***	.14	.88 ***					
5 Functional Coordination	4.97**	1.09	.13	.27 ***	.89 ***	.55 ***				
6 Project Mgr Authority	.23*	.21	-.06	-.04	.11	.11	-.08			
7 Component's Interdependency	5.01	1.56	-.03	.02	.08	.08	.00	.06		
8 New Design Ratio	.87**	.22	.13	.10	.13	.13	.04	.04	.25 ***	
9 Supplier's Design Contribution	.33	.23	-.03	-.13	-.04	-.04	-.11	-.02	-.09	-.06

*$p<.10$; **$p<.05$; ***$p<.01$ (§ Significant level for means: t-test for the difference in sample means)

Schedule/Cost Performance

Table 3 shows regression results for project performance in schedule and cost. The results show that organizational coordination required to perform well significantly differ between component design with and without inter-project interactions, and generally support our hypotheses. First, in component design without inter-project interactions, as most of the past studies found out, project coordination, not functional coordination, is particularly important to perform well in schedule and cost. Secondly, in component design with inter-project interactions, functional coordination is important to manage inter-project coordination even for schedule/cost performance. Thirdly, the influence of project coordination as well as total coordination on performance is stronger in component design with inter-project interactions than in those without interactions. In addition, project manager's authority contribute to performance significantly in only those projects with inter-project interactions.

In addition to the differences in the influence of organizational coordination variables, other design characteristic variables also affect performance differently between these two types of component design. A component's interdependency with other parts of the product and the extent of supplier's contribution have a significant negative effect on performance only in component design with inter-project interactions. Accordingly, respondents at the U.S. firms tended to rate the performance higher than the Japanese respondents. This may have been caused by the low return rate from the U.S. firms, who may have chosen only high-performing component design projects as pointed out earlier. In any case, this bias does not affect the results regarding the general theoretical propositions posed in this paper.

Table 3. Regression Analysis for Project Performance in Schedule and Cost

	With Inter-project Interactions (N=106)		Without Inter-project Interactions (N=119)	
Independent variables	1	2	3	4
Constant	2.32 ***	2.35 ***	3.27 ***	3.34 ***
Total Coordination	0.43 ***		0.19 *	
Project Coordination		0.27 **		0.22 *
Functional Coordination		0.16 *		-0.03
Project Mgr Authority	0.73 *	0.68 *	-0.61	-0.72
New Design Ratio	0.16	0.16	0.70	0.65
Component's Interdependency	-0.12 **	-0.13 **	-0.07	-0.07
Supplier's Design Contribution	-0.94 ***	-0.92 **	-0.02	-0.07
Nation (US;0, Japan; 1)	-0.23	-0.25	-0.76 **	-0.73 **
Squared Multiple R	0.28	0.29	0.12	0.13

*p<.10; **p<.05; ***p<.01

Design Quality Performance

There are smaller differences between the two kinds of component design regarding the influence of organizational coordination on design performance than on schedule/cost performance. Design quality performance is significantly affected only by functional coordination in both types of component design. However, total coordination has a significant influence on design quality only in component developments with inter-project interactions. In addition, supplier's contribution in design also has a stronger negative influence on design quality performance in component design with inter-project interactions.

Table 4. Regression Analysis for Project Performance in Design Quality

	With Inter-project Interactions (N=106)		Without Inter-project Interactions (N=119)	
Independent variables	1	2	3	4
Constant	3.67 ***	3.64 ***	5.05 ***	4.97 ***
Total Coordination	0.28 ***		0.15	
Project Coordination		0.07		-0.09
Functional Coordination		0.21 **		0.23 **
Project Mgr Authority	0.49	0.55	-0.62	-0.48
New Design Ratio	0.18	0.18	0.40	0.46
Component's Interdependency	0.04	0.05	-0.04	-0.03
Supplier's Design Contribution	-0.71 *	-0.74 *	-0.45	-0.40
Nation (US;0, Japan; 1)	-0.85 ***	-0.83 ***	-1.25 ***	-1.28 ***
Squared Multiple R	0.26	0.27	0.25	0.27

*p<.10; **p<.05; ***p<.01

Table 5 summarizes the influence of coordination and task variables on performance. It is evident that organizational requirements significantly differ between component design with and without inter-project interactions. In component design development with inter-project interactions, organizational coordination, in general, tends to have a stronger impact on performance than in design without those interactions. The influences of both project coordination and functional coordination are stronger in design with inter-project interactions. Functional coordination, which directly involves engineers of multiple projects, affects schedule/cost performance only in design with inter-project interactions. In addition, project coordination has a stronger influence on performance in design with multi-project interactions.

Complexity caused by other task characteristic elements, such as component interdependency with other parts of the product and the degree of supplier's involvement in design, seem to impose more penalty on component design with inter-project interactions. This may be because component design without inter-project interactions is simpler than design with interactions, and thus it may be easier to manage the complexity of component interdependency and supplier's involvement more effectively.

The results of this survey indicate that, in order to effectively manage schedules and costs for component design across multiple projects, not only stronger functional coordination but also stronger project coordination is needed. In addition, other factors that impose further complexity on the organization, such as component interdependency and supplier's involvement, tend to cause difficulties to the organization in component design with inter-project interactions.

Table 5. Summary of the Regression Analyses

		The Degree of Coordination			Component Inter-dependency	Supplier's Contribution
		Total	Project	Functional		
With Interactions	Schedule/Cost	***	**	*	**	**/***
	Design Quality	***		**		*
Without Interactions	Schedule/Cost	*	*			
	Design Quality			**		

*p<.10; **p<.05; ***p<.01

5. Conclusions and Further Research

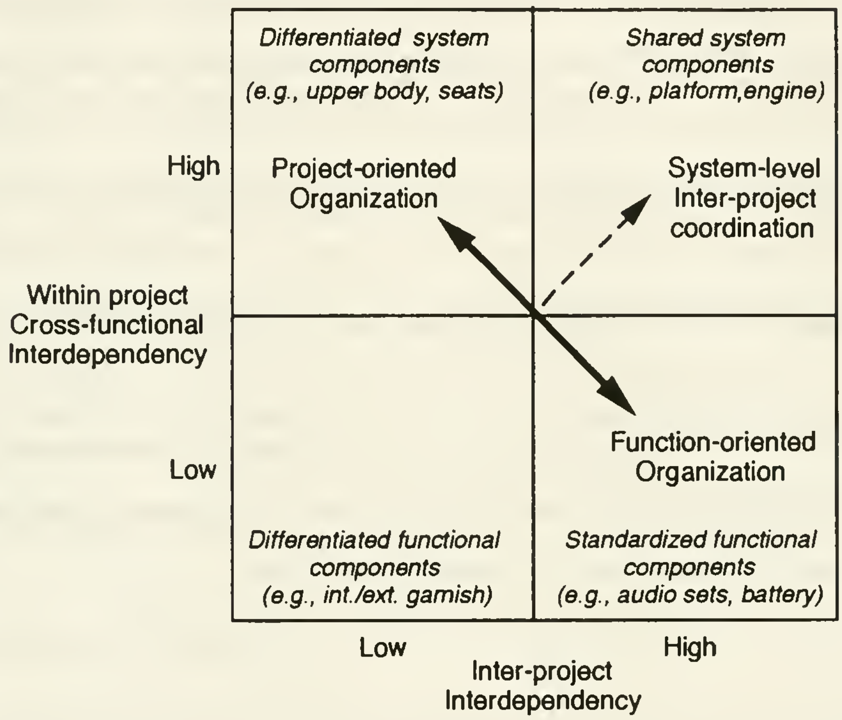
This paper first proposed a framework to analyze strategies for multiple new-product development projects by developing an inter-project strategy typology. Using this framework and data of 223 new products at 21 worldwide auto manufacturers, we argued that high performers with respect to market share growth during the 1980's more often utilized a concurrent design transfer strategy, in which close coordination between projects was required. This result supported our proposition, by managing inter-project interactions effectively, concurrent design transfer is theoretically the most appropriate way both to develop multiple products quickly and to maintain design of these products that are relatively new under limited financial and organizational resources.

The second part of this paper examined how organizational requirements differ for component designs with and without inter-project interactions. The questionnaire survey of 215 component engineers provided evidence that organizational coordination required to manage these two types of component design - with and without inter-project interactions - significantly differ, particularly with respect to schedule/cost performance. While only project coordination has a significant influence on schedule/cost performance in design without inter-project interactions, both functional coordination and project coordination have a strong impact on performance of design with inter-project interactions. Moreover, the magnitude of the impact of project coordination on the performance of design with inter-project interactions is bigger than in those without interactions. We also found that inter-project interactions make it difficult to deal with other factors that impose complexity on the organization such as intra-project component interdependency and supplier's involvement. This result theoretically implies that a different model is required to predict the relationship between project strategy, organizational coordination, and performance for projects with inter-project interactions.

These findings imply that effective management of multiple new product development projects, rather than focusing on individual projects separately, can be a competitive advantage in the market on the presumption that financial and engineering resources are limited. In addition, we also found evidence that managing inter-project interactions effectively is organizationally difficult and requires a substantially higher degree of organizational coordination both within a function and across functions than in a project that is independently managed. The coordination requirements for component design with inter-project interactions are so different from those without inter-project interactions that different organizational structures and processes are likely to be needed. This paper has not discussed specific processes or mechanisms with which project organizations actually manage inter-project coordination. In this area, there are many questions to be explored regarding appropriate means to coordinate across multiple projects. First, there is an issue of task partitioning regarding specific engineering tasks that are related to multiple projects (von Hippel, 1990). For example, components like air conditioners that are relatively easy to share across a number of projects without substantial modifications may be designed by the same engineers across multiple projects. Second, different groups of people may have to be responsible for managing inter-project coordination effectively, depending on the nature of coordination. For example, inter-project coordination may be well-managed by direct coordination between engineers in multiple projects, functional managers in each engineering function or project managers in multiple projects, or by an independent coordinating group. Third, selecting appropriate coordination means and effectively implementing them are also important issues, which include formal or informal meetings, long term planning for sharing components across multiple projects, and computer systems such as CAD that may facilitate design transfer between projects.

In order to explore such coordination processes, it is essential to analyze in detail the nature of different component design tasks that affect requirements of different types of organizational coordination. Project and functional coordination requirements depend on a component's cross-functional interdependency and inter-project interdependency. Using these two dimensions, Figure 7 categorizes different types of components into four groups. A group to which a specific component belongs is conceptually determined by a firm's inter-project strategy for a specific component. However, it also at least partially depends on the nature of the component with respect to design interdependency with other components, and on the benefits of perceived differentiation from other products in the market. The degree of differentiation benefits for a specific component is determined here by the degree of contribution the component has in persuading customers to perceive one product as different from other products the firm offers. For example, the upper-body design directly visible to the customer is usually distinctive to each product rather than shared across multiple projects. Therefore, upper-body design need not to be coordinated with other projects. However, the upper body design should be extensively interdependent with other parts of the automobile design, such as the suspension system and interior that also need to vary with each product to make it distinctive. These type of components, which we call *differentiated system components*, need to be well managed through a project-oriented organization.

Figure 7. Design Interdependency and Organizational Coordination



On the other hand, there are some components for which the benefits of differentiation in the market are relatively small. For example, firms do not extensively differentiate audio systems or batteries for each different product and may want to standardize these designs among different projects. This type of component design is relatively independent of other parts of the automobile design. We call this type *standardized functional components*, which may be managed effectively through a function-oriented organization. We also label the type of components that have a strong interdependency along both dimensions, intra-project and inter-project, as *shared system components*. There are many components of this type, which range from major components such as platforms (underbodies and suspension systems) and engines, to small components such as brakes and door-lock systems.

This framework for different types of components raises two related questions. The first is how firms can structure an organization to manage effectively the development of significantly different design tasks, which also have to support the project strategy. Since simple matrix organization does not seem to be adequate, there may have to be extensively differentiated mechanisms within a matrix organization. Secondly, how firms can manage the development of *shared system components*, which cannot be coordinated by either traditional project-oriented or function-oriented matrix organizations, because this type of component must be coordinated within the context of a specific project as a system. Few if any empirical or theoretical studies have addressed this problem of coordination between multiple systems. Companies need either strong mechanisms above the matrix organization such as, executive-level long-term planning offices, or organizational structures and processes that enable system-level coordination across multiple projects. In order to analize this and related issues, we believe that in-depth case studies are appropriate as a first step, and we are thus continuing this research through extensive interviews of project managers and engineers at major automobile manufacturers.

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Appendix 1. Change Index of Platform Design

Change in Wheelbase and Treads

Points

0: Both wheelbase and tread are the same

1: Only either wheelbase or tread are new

2: Both wheelbase and tread are new

Change in Suspension Design

Points

0: Suspension system and design are the same; modification in geometry

1: Suspension system is the same, but design is new

2: Suspension system is new

If a sum of the points in both areas is three or more, platform design is defined as new.

Appendix 2. Distribution of Transfer Lag