Multi-Project Management: Strategy and Organization in Automobile Product Development

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Numerous researchers have undertaken studies of how effective and efficient new product development projects have been in various industries. Most of the empirical research has focused on individual projects. In automobiles and other industries, however, most large manufacturers have several product lines and constantly develop new products to replace existing products or to add completely new product lines. Each project within a firm has at least some linkages both technologically and organizationally with other on-going projects and past projects within the firm. Therefore, managing the way different projects interact organizationally or relate to each other technically is extremely important for a firm to leverage its engineering and financial resources, as well as an existing technology and design, across as many projects as possible. Nonetheless, there has been little research that explores multi-project management and its impact on either market or organizational performance.

The purpose of this research project is to explore product-development strategies and organizational processes used in the management of multiple projects. An underlying hypothesis is that differences in inter-project strategy and management should influence the efficiency and effectiveness of an entire firm in new product development, as well as the performance of individual projects. Specifically, this research project will examine three questions. First, what is the potential influence of different types of inter-project strategies on market competitiveness? In this section, we argue that managing concurrent interactions effectively between multiple projects within the firm is a potential source of competitive advantage to the extent that firms can transfer technology or designs quickly across multiple projects. Second, what is the influence of different types of inter-project strategies on project productivity and lead time? Third, what is the appropriate organizational structure and process to manage different types of project strategies, given the impact of technological and organizational interdependencies on organizations? In order to answer these questions, we use publicly available data, a questionnaire survey, and detailed interviews of engineers and program managers in Japanese, U.S., and European automobile firms.

This study is one of the first explorations of the effectiveness and efficiency of multi-project product development over time. Conceptual frameworks and findings for multi-project strategy and management will contribute to the understanding of product development management and strategy by both researchers and practitioners.

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 on performance measures for individual projects. A stream of studies have explored factors that led individual projects to success in the marketplace (Maidique, 1984; Rothwell, et al., 1974; Zirger and Maidique, 1990). In addition, particularly in recent years, given the accelerating pace of changes in technologies and customer needs, a number of studies have focused on the speed and the productivity of individual projects (Imai et al., 1985; Gupta and Wilemon, 1990; Clark and Fujimoto, 1991; Cusumano, 1991; Cordero, 1991; McDonough III and Barczak, 1991; von Braun, 1991; Crawford, 1992). One common finding in this area of studies is that in order to shorten the development lead time, strong cross-functional coordination is needed. For example, Clark and Fujimoto (1991) describe a "heavy-weight" project manager who facilitates quick completion of a project by integrating different functions such as design engineering, manufacturing engineering, and marketing, and by managing overlaps among these functions in parallel effectively rather than proceeding sequentially. At MIT research project also referred to this approach as "lean product development" (Womack et al., 1990).

At the same time, various studies report that leading manufacturers, particularly the Japanese, tend to develop new products faster and replace them much more frequently than U.S. or European competitors, resulting in shorter product life cycles and broader product lines (Abegglen and Stalk, 1985; Dertouzos et al., 1988; Womack et al., 1990; Stalk and Hout, 1990; Peters, 1992). These studies argue that this difference in product development performance has been one of the major reasons, along with manufacturing skills, for the growth of Japanese manufacturers in global markets.

However, in recent years even Japanese manufacturers became more concerned with efficiency. They have faced severe profitability problems, which are related at least in part to the high costs of developing and manufacturing so many new products or product variations in markets such as for automobiles and consumer electronics. In these markets, 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). These firms need to improve their efficiency in developing multiple new products, yet maintain as much as possible the frequency of new product introductions and design quality of the individual projects. Developing multiple new products through relatively autonomous project-oriented organizations, which tend to use many proprietary components for each project, requires extensive financial and engineering resources. In order to achieve economies, firms may want to reuse effectively existing technologies and design within the firm or may want to share more components among multiple product development projects without sacrificing an individual product's design quality and distinctiveness.

An essential area in research on product development relating directly to the issue of how to produce multiple products and variations more efficiently has been overlooked. This is the management of multiple new-product development efforts over time from the perspective of the corporation as a whole. The key issue is how to balance what is optimal for an individual project with what is optimal for the firm overall - in other words, how "heavy" should heavyweight project managers be? High levels of engineering productivity in individual projects may contribute to making a firm overall more efficient in product development. But, at the same time, developing a successful stream of new products over many years, as well as taking 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.

This set of issues contains critical questions related to both project strategy, and organizational structure and process:

1) How should a new product project strategically be related to existing technology and design from past projects and to projects for other product lines? In addition, at the corporate level, what is the appropriate evolution strategy of a multi-project portfolio over time with respect to inter-project technological relatedness?

2) What is the appropriate organizational structure and process to manage different types of multi-project strategies? In particular, how can the balance and the tradeoffs be assessed between increasing distinctiveness and integrity of individual projects, and managing the relatedness with existing technology or with other projects for other product lines?

Previous Research on Product Development

A few of studies on product development have focused on the extent of technological or market relatedness to past projects within the firm (Johnson and Jones, 1957; Roberts and Berry, 1985), or assessed the different impacts of radical and incremental innovations on organizations (Dewar and Dutton, 1986; Ettlie, et al., 1984; Tushman and Anderson, 1986). Most studies, however, have primarily focused on individual projects without systematically exploring strategy and management of multiple projects over time. This gap in the research remains, even though, in recent years, some researchers have started emphasizing the importance of planning for and managing the evolution of a sequence of new product projects (Hayes, et al., 1988; Wheelwright and Sasser, 1989; Clark, 1989; Wheelwright and Clark, 1992; Cusumano, 1992).

With regard to the automobile industry, 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 overlap among stages such as product planning, product engineering, and process engineering.

Clark elaborated on these results in a 1989 paper that focused on showing how Japanese projects used more unique parts and higher engineering productivity than their U.S. and European counterparts. He concluded that this was primarily because Japanese firms generally 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 corporate-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 or engineering hours at the project level and the performance variables at the corporate 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 management of the multiple product development projects.

Overview of this Study

The purpose of our study is to build on this research and explore product-development strategies and organizational processes used in the management of multiple projects. 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. 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 its competitors.

Specifically, this paper examines three questions. First, this study will explore the influence of different types of multi-project strategies on corporate-level market performance. 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 firms may create competitive advantage in the market by transferring technology and designs quickly across multiple projects. Firms may effectively leverage their engineering and financial resources through this rapid design transfer. We investigate this proposition by referring to publicly available data of technological features used in 211 new car products introduced by 17 automobile manufacturers between 1980 and 1991. Second, we discuss the influence of different inter-project strategies on lead time and engineering hours at the project level. In this analysis, we surveyed project managers at 10 automobile firms: seven in Japan and three in the U.S, a total of 103 different new product projects, for which one project manager was responsible. Third, this study examines the appropriate organizational structure and process to manage different types of project strategies, given the impact of technological and organizational interdependencies on organizations. In particular, we explore coordination requirements and mechanisms to manage interactions between concurrent projects. In order to answer this question, we use a questionnaire survey of 225 engineers at all ten major manufacturers in Japan and the U.S.

Scope for Multi-project Management

Large automobile manufacturers have several product lines and constantly develop new products to replace existing products or to add new product lines over time. Each project within a firm has at least 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 core design of their previous models, and others use designs from other product lines. Some projects may choose to develop a new technology and design from scratch (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. This perspective of project strategy requires more complicated consideration than the distinction between radical innovation and incremental changes, which numbers of past studies have discussed (Dewar and Dutton, 1986; Ettlie, et al., 1984; Tushman and Anderson, 1986).

Firms also need to plan for the frequency of new development projects, both to replace existing products, which determines the product life cycle of these products, and to expand the breadth of available product lines (Miller, 1988; Kekre and Srinivasan, 1990; von Braun, 1991). This frequency, which is often discussed in the same line of arguments as accelerated product development, becomes a central competitive dimension because some manufacturers appear to be much more prolific in their new product introductions than others. A new product introduction provides firms with an opportunity to incorporate a new technology into their products in the marketplace as well as up-dated modifications. It is not very useful to discuss project strategy by isolating an individual project without this dynamic perspective of product introductions. For example, the same incremental change strategy may have a different impact on its market competitiveness depending on how quickly the modification is made.

Figure 1 exhibits actual examples of different multi-project strategy patterns in the 1980's from three major automobile manufacturers in the U.S., Europe and Japan. This picture illustrates different ways multiple projects within the firm are related to each other with respect to platform design. In this example and the major portion of our study, we focused on the design strategy for platforms in new car development projects. A platform consists of floor panels and a suspension system, and defines the architecture of automobile, because the platform significantly affects the basic characteristics of the rest of the components, including the body structure, drive-train type and engine/transmission size. In addition, selection of a specific platform design determines the general level of design functionality of the whole product. Not surprisingly, developing a new platform design requires more financial and engineering resources than most other components.

The black circles in Figure 1 indicate new products that utilized platform designs built by each firm more or less from scratch. New product projects indicated by white circles enhanced platform designs already existing within the firm. When projects used enhanced platform designs, arrows in the figure specify the base design on which each project was based - either the new product's direct predecessor or a platform from another product line.[1]

Firm A developed a new platform design only once in 1980, and the following projects in the 1980's continued to use the same old platform design in multiple product lines over 11 years. Firm B, on the other hand, never shared the same platform design between different product lines and tends to develop a new and unique platform design for each new product. On the other hand, when Firm C developed a new platform design for one of its product lines, it transferred the new design quickly or almost concurrently to other product lines. In this way, the firm introduced new products frequently without repeatedly using the old design, as Firm A did.

As this example indicates, we believe that critical strategic and organizational issues can be uncovered by studying multi-project management. How one project interacts with other projects may affect the competitiveness of all products and the firm overall. This type of multi-project strategy can only be effectively planned and implemented above the individual project level. In addition,

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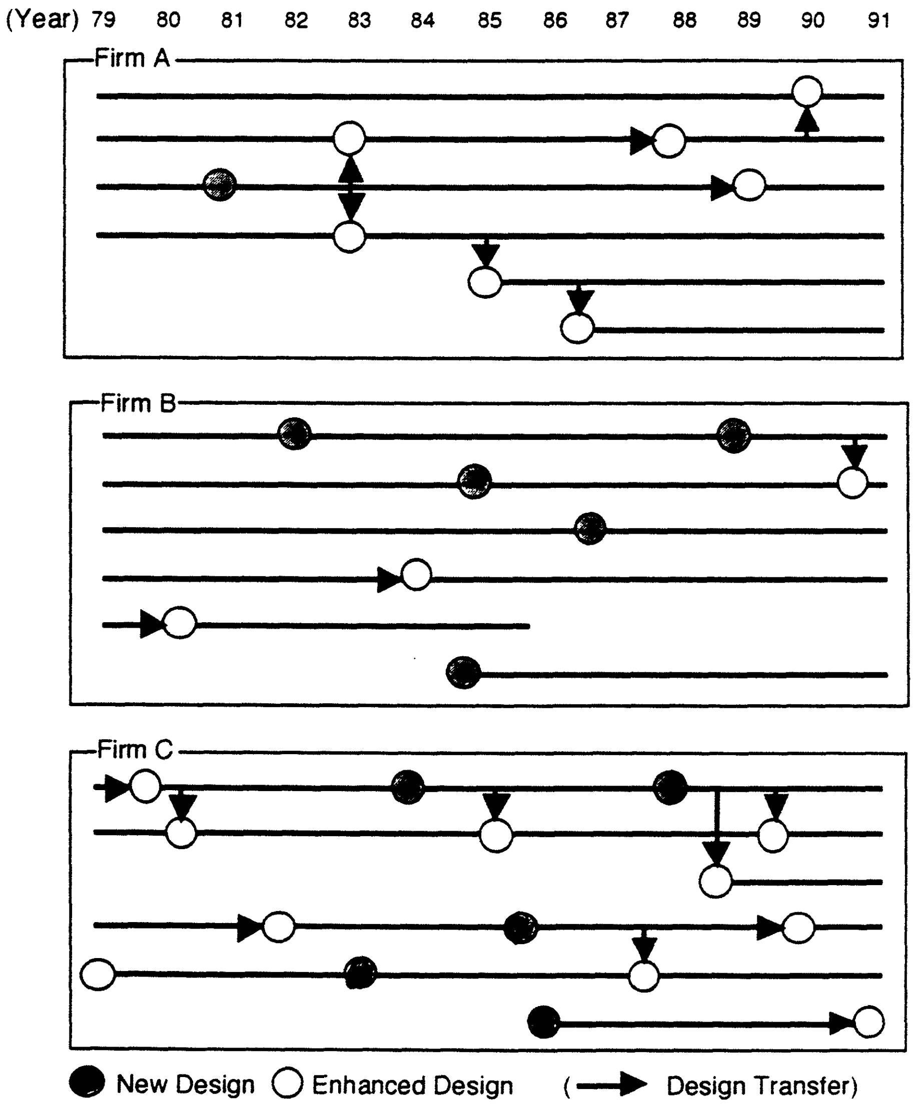
1 Data collection methodology is described in the next section. Here, this example is only for illustration purposes.

organizational capability to transfer designs effectively between multiple projects may provide a unique competency within a firm through different outcomes in multi-project strategy as well as through an effective inter-project learning. Moreover, because managing the inter-project linkages effectively may require extensive integration across a firm, the patterns firms choose regarding inter-project linkages may have an influence on their organizational competitiveness as a whole.

Figure 1. Examples of Different Multi-project Strategy Patterns

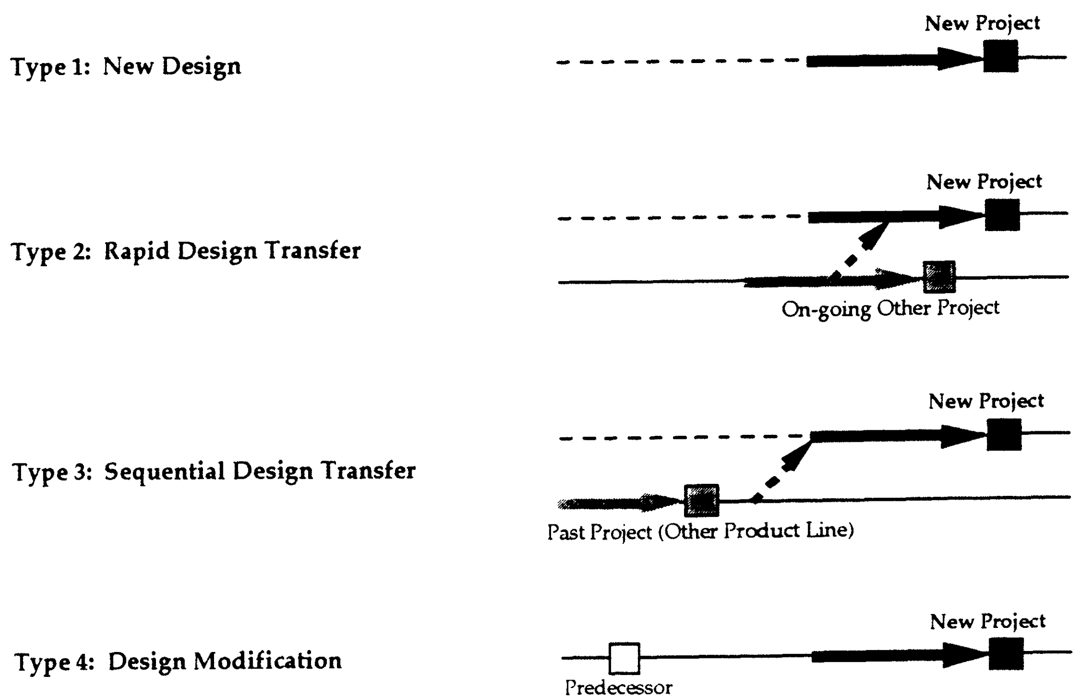


2. Influence of the Inter-project Strategy on Market Competitiveness

2-1 Typology of Inter-Project Strategy and Design Age

Firms have various alternatives for inter-project strategies used in new product development. In order to analyze complicated patterns of different multi-project strategies such as those in Figure 1, Figure 2 decomposes this and presents an inter-project strategy typology. This typology categorizes new product development projects into four types, depending on the extent of changes, sources of the base design, and their potentially different impacts on organizational structure and process. In this analysis, as mentioned earlier, we focused on design strategy of the platform in new car development projects.

Figure 2. Typology of the Inter-project Strategy



The extent of change differentiates a new project whether its core design is newly developed or transferred and modified from other preceding projects within the firm. New product projects that develop their own new core designs (e.g., platform design) 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 ongoing other project, an existing other product, or the new project's direct predecessor product. These three types are labeled here as *rapid design transfer*, *sequential design transfer*, and *design modification*, respectively.

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 concentrate on creating a new technology and design for the new project. While the project's engineering task requirements should be the highest among the four because the design is new (Clark, 1989), both coordination costs with other projects and design constraints are low. The project does not have to be coordinated with other projects or follow design constraints derived from an existing design base. This type of project is appropriate to incorporate the latest technology and design into the new product.

The next two types of projects transfer and share a core design from other projects within the firm. In the second type, *rapid 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) some of the development phases 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 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 as in rapid design transfer. In addition, design constraints may be high because mutual adjustments between projects on the core design are no longer possible,[2] and yet the new project needs to adjust it to the base core design from other product line.

The last type, *design modification*, refers to a new product project that develops a core design based on that of a direct predecessor product. 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. In this definition, the extent of modification from the base design does not have to be less than that of rapid design transfer or sequential design transfer. 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 useful features 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 is based was first introduced. The concept of the design age is particularly critical in an analysis of inter-project strategy, because it measures how quickly a new design is leveraged by multiple projects within the firm. 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 differentiates design transfer strategies, either rapid design transfer or sequential design transfer, depending on how quickly new design is transferred between multiple projects. Design age of a new product using the 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. Design age of a new project that develops a core design from scratch using the new design strategy is the smallest, which is defined as zero.

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2 This discussion of hypothetical differences between rapid 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

2-2. Impact of Inter-project Strategy, New Product Introduction Rate, and Average Platform Design Age on Market Performance

There are two critical company-level output dimensions that are closely related to inter-project strategy: new product introduction rate and average platform design age. The new product introduction 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 number of studies provided evidence that frequent product introductions have a positive influence on market share growth. A higher new product introduction rate makes it possible for a firm to replace existing products for improved ones more quickly, or enter new market segments more frequently, than competitors (Miller, 1988; Fujimoto and Sheriff, 1989; Kekre and Srinivasan, 1990; Womack et al., 1990). Broader product lines may enable a firm to meet consumer needs more effectively, which leads to higher market share (Bagozzi, 1986; Kotler, 1986; Bower and Hout, 1988). The impact of the new product introduction rate on market performance is particularly important in industries such as automobiles where[3]:

1) technology and design steadily improve every day, instead of radical improvements only once in every decade, and products compete in the marketplace by a marginal superiority; and

2) customer expectations are fragmented and change at a rapid pace, which are predicated by current fashion trends and social values; freshness in styling and model introduction, in addition to performance functionality, has a significant influence on sales.

In order to increase the new product introduction 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 want to save their resource investments and to maintain their new product introduction rate, they may have to decrease new components in each project. A project that develops more new components generally requires more lead time and engineering hours

[3] Clark and Fujimoto (1991) also discussed the world car market using the same set of assumptions.

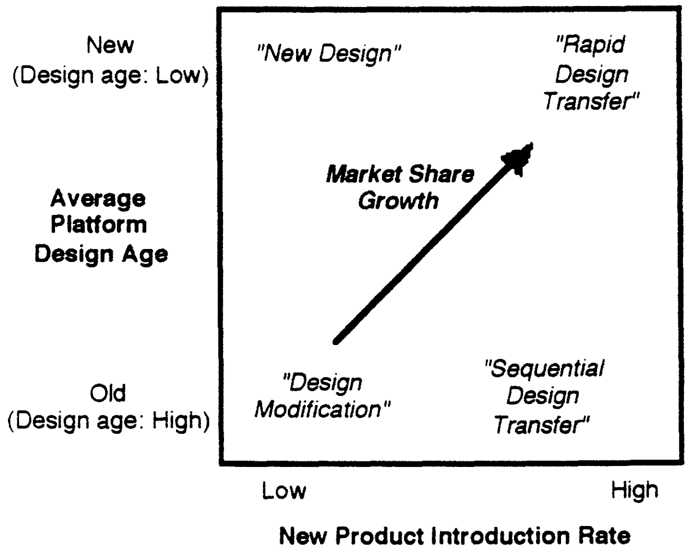
(Clark, 1989). Thus, it may not be a reasonable choice for a firm that pursues a high new product introduction rate to utilize extensively the new design strategy.

Following this concept, in other words, firms may want to use existing technology and design repeatedly in multiple projects over time to make the most of their financial and engineering resources and existing design in developing multiple products. However, if firms use old design and technology repeatedly, repeated use of the same old design may have a negative impact on market competitiveness. 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, the negative impact on a firm's market competitiveness may 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. Automobile firms successful in market share growth may develop more new products without introducing older designs unlike 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 inter-project strategies that differ from those of low performing manufacturers in order to mitigate this tradeoff.

Thus we have two hypotheses regarding the relationship among different inter-project types, design age, new product rate, and market share growth performance, as exhibited in Figure 3. First, firms that develop more new products than their competitors without reintroducing older designs may increase market share. Second, in order to both increase new product introduction rate and maintain a low average platform design age of the new projects, a firm may choose to use rapid design transfer strategy. This allows a quick design transfer among multiple projects while a design is still relatively new. An extensive usage of the transfer strategies, rapid design transfer or sequential design transfer, may provide firms with a greater advantage to develop more new products than the other two inter-project strategy types by sharing design among multiple projects. However, a new product using sequential design transfer results in incorporating older technologies into the product than those products using rapid design transfer. On the other hand, 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 introduction rate. Focusing on design modification is not advantageous either in terms of the new product introduction rate or the average platform design age.

Figure 3. Hypotheses on Inter-project Types



2-3. Sample Characteristics and Measurements

The sample in this study covers the 17 largest auto manufacturers in the world, including five Japanese (Toyota, Nissan, Honda, Mazda, Mitsubishi), three U.S. (GM, Ford, Chrysler), and nine European producers (VW/Audi, Mercedes-Benz, BMW, Opel, Ford of Europe, Peugeot/Citroen, Renault, Fiat). These firms introduced 211 new car products between 1980 and 1991. Data on new product development in the industry were primarily collected from Auto Review, an annually published industry journal that covers design features in detail and introduction dates for all new products worldwide[4]. Interviews with about 120 engineers and 25 project managers in these firms worldwide were also conducted for clarification.

We defined a new product as a model designed within a single project and with mostly 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 the Mercury Sable, count as only one new product. Whether two or more new variations were in fact developed together within one project or separate projects is critical to this study. This affects the total number of new projects and the nature of their interrelationships. Most new car product cases, such as the Taurus and the Sable, are openly discussed in Auto Review or other industry journals mentioned earlier. For unclear cases we have had to rely on interviews with company engineers.

Data were divided into four three-year time periods of 1980-1982, 1983-1985, 1986-1988, and 1989-1991; the combination of 17 firms and four time periods makes 68 combinations. Among the 68 combinations, four cannot be used because four firms introduced no new products during one of the four time periods, which resulted in 64 data points of company-level strategies[5].

New Product Introduction Rate

The new product introduction rate was calculated for each manufacturer during each of the three-year periods by the ratio of the number of new product introductions divided by the number of product offerings in the base year.

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4 We also refereed to automobile magazines including Motor Trend, Car and Driver, Car Graphic, NAVI, and Car Styling, as well as a weekly industry journal, Automobile News, for detailed information on projects.

5 We also conducted a sensitivity test, using six two-year periods, three four-year periods, and two six-year periods. All of them provided us with similar results is this division scheme. However, we believe that a two-year period is too short to capture a dynamic multi-project strategy. Moreover, the longer period scheme weakens the impact of distinctive strategies, because aggregate performance data are used in this study.

Inter-project Strategy Types and Average Platform Design Age

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).

Platform design age for new product projects that develop new platform designs without any preceding base design, which is a new design strategy, is zero as defined earlier. Design age for projects that develop new products based on platforms from other projects is measured by the difference in time between the introduction of the new product and when the base product was first developed. Average platform design age is calculated for all new products a firm introduced during a three year period.

Among projects that are based on a preceding base platform, those which develop a new product based on the platform design of the predecessor model are categorized as design modifications. Those which shared platform designs with any preceding projects for other product lines are either rapid design transfers or sequential design transfers. As defined earlier, the distinction between rapid and sequential transfers is determined by the transfer time lag, which is the same as the platform design age.

We categorized new projects into rapid design transfer when a transfer from a base project occurred within 2.0 years of the introduction of the base design for several reasons. Our in-depth interviews with engineers revealed that if the time lag is longer than about two years, then there does not usually need to be much overlapping among or coordination between projects. In our definition, a key factor that conceptually differentiates rapid design transfer from sequential design transfer is whether overlapping among the new project and the base project in platform design exists. The figure 2.0 years is also reasonable, because it is about 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). Given the nature of platform design, overlapping is likely to exist when the lag is within

2.0 years. 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.

Usage of different inter-project strategies was measured by the percentage of each inter-project strategy types out of all new car products introduced by a firm during a three-year period.

2-4. Results and Discussion

Figure 4 shows the trend of the total number of new product introductions (a thick line referring to the left scale) and the percentage of each inter-project strategy types used by 17 firms in the world during four three-year periods between 1980 and 1991. The total number of new product introductions increased rapidly after 1989. Usage of rapid design transfer strategy also increased sharply in the middle of the 1980's. This trend implies that management of overlapping among multiple projects as opposed to a single project management has become more important than before. The percentage of rapid design transfer, 20-25%, means that almost 40 - 50% of projects needed to be coordinated, because each rapid transfer involves overlapping with at least one other project from which the platform design is transferred.

Figure 4. Trend: Usage of Different Inter-project Strategy Types

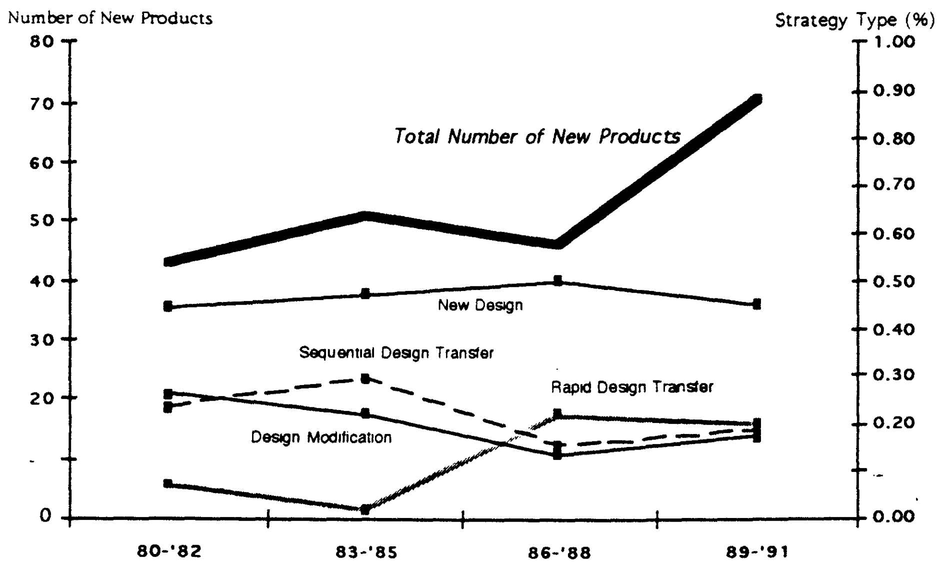


Figure 5 illustrates the relationship we found between market share growth in dollars[6], the new product introduction rate and the average platform design age for the 64 data points, each representing the product strategy of one firm during a 3-year period. White circles indicate high performing firms with market share growth of 10% or higher during the three-year period. X labels firms that declined in market share by more than 10%, while black dots identify middle performers. As our hypothesis suggests, firms in the high new product introduction rate/small average platform design age region tend to have gained more market share than the others. Firms in the region with a lower new product introduction rate with an older average platform design age mostly lost market share.

Figure 5. New Product Rate and Average Design Age

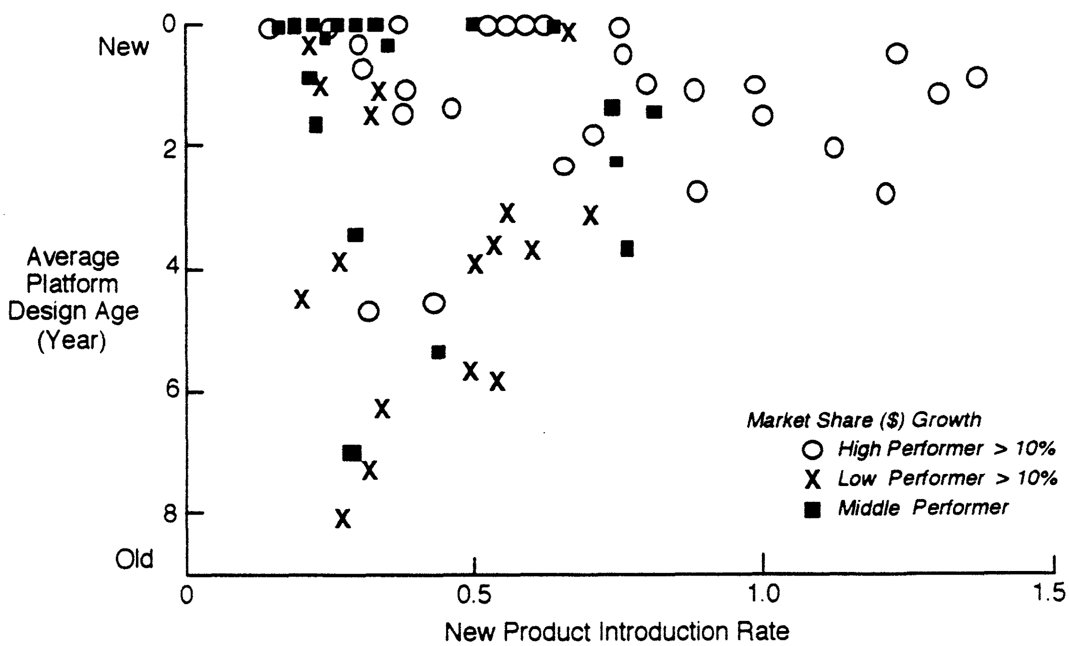


Table 1 further analyzes this relationship in regression models with variables including firm size, which is measured by the number of product offerings of each firm at the beginning of a base year, nationality of firms, and four different time periods to control for potentially different market

[6] Market share was calculated in revenue from car sales in the U.S., Japan, and EC markets. This revenue was calculated by the total sales for each product multiplied by its average sales price. The average sales prices we used were those in the U.S. market, which were adjusted to 1991 prices. For those car products not available for purchase in the U.S. market, prices were estimated by their equivalent products in the U.S. market with respect to size and equipment level.

conditions each firm may have faced during each of four periods. Market share growth of the previous period is also in the regression models to control for firm-specific influence of performance in a previous period on market performance. The new product introduction rate and average platform design age significantly influence market share even after controlling for these factors, as shown in model 2.

Table 1. Regression Results for Market Share ($) Growth

Independent Variables	1	2	3	4
Constant	0.00	0.00	0.00	0.00
New Product Introduction Rate		0.36 **		0.41 **
Average Platform Design Age		-0.34 ***		
Inter-project Strategy (% of New Products)				
New Design			0.23	0.27
Rapid Design Transfer			0.47 ***	0.46 ***
Sequential Design Transfer			0.21	0.20
Design Modification			-	-
Market Coverage (# of Product Offerings)	-0.18	-0.07	-0.18	-0.11
Δ Market share ($) in previous period	-0.26 **	-0.19 *	-0.29 **	-0.27 **
Period (Dummy)				
80 - 82	0.09	0.11	0.22	0.27 *
83 - 85	-0.15	-0.09	0.01	0.07
86 - 88	0.05	0.07	0.03	0.11
89 - 91	-	-	-	-
Region (Dummy)				
US	-0.21	-0.10	-0.20	-0.19
Japan	0.29 **	0.02	0.17	-0.06
Europe	-		-	-
Adjusted Squared Multiple R	0.22	0.34	0.32	0.37
Sample Size	64	64	64	64

Statistically Significant at: *** 1% Level, ** 5% Level, * 10% Level
Source: Analysis of publicly available data

In models 3 and 4, categorical variables, which is usage of inter-project strategy, are used, which also significantly predict market share growth. An extensive use of the rapid design transfer strategy has a strong positive influence on market share growth, in which designs are transferred quickly between multiple projects. The rapid design transfer strategy enables firms to achieve both a high new product introduction rate and a low average platform design age.

Table 2 categorizes the 64 data points into four different strategic groups depending on which inter-project strategy a firm used most extensively. First, firms that had more than 25% of their new products as rapid design transfers are categorized into Group 2. Among the rest of the data points, firms in Group 1 used more new designs than any other inter-project strategies in their new product development. Similarly, Group 3 and Group 4 primarily used sequential design transfer and design modification, respectively.

Table 2. Performance Comparison among Strategic Groups

Strategic Group	Group 1	Group 2	Group 3	Group 4
# of Observations	23	15	13	13
% of Inter-project Strategy				
• *New Design*	**0.92**	0.46	0.23	0.31
• *Rapid Design Transfer*	0.00	**0.37**	0.00	0.01
• *Sequential Design Transfer*	0.04	0.07	**0.71**	0.16
• *Design Modification*	0.04	0.10	0.06	**0.52**
New Product Introduction Rate	0.42	0.77	0.46	0.46
Average Platform Design Age	0.25	1.09	3.63	4.43
Δ Market Share ($)	0.09	0.23	-0.03	-0.12
Δ Number of Product Offerings	0.05	0.29	0.18	0.08
Δ Market Share ($) /Product Offering	0.06	0.01	-0.16	-0.18

Differences among the four groups are all significant at 1% level (One-way ANOVA)
Source: Analysis of publicly available data

Firms in Group 2 developed more new products with relatively new average platform designs, and gained the largest market share, approximately 23% compared to the previous 3-year period. Firms that mainly reused old existing designs, which are categorized into Group 3 and 4, with an extensive usage of sequential design transfer or design modification strategy, lost market share. In other words, in order to increase market share, it seems useful for firms to develop new designs and, at the same time, leverage a new design quickly in other car products, rather than only developing a new design or transferring a design slowly to other projects. Firms categorized into Group 1, which primarily used the new design strategy had the largest increase in the ratio of their market share divided by the number of product offerings, although this appears to be the result of both the impact of new models on market growth and the focus of these companies on a limited number of product lines.

We realize that variables used here to predict market performance are limited. 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. At the same time, however, this set of data demonstrates that even a limited number of variables related to multi-project strategy explained market share growth reasonably well (adjusted R-squared ranges from 0.32 to 0.37).

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 seemed to transfer new designs among multiple projects quickly, which contributed to both higher new product introduction rates and relatively new average platform design ages. It also appears that, in order to implement rapid design transfer, two or more different projects have to coordinate with each other. If rapid design transfer sacrifices project performance and productivity, it may not be a good strategy. In the next section, we explore empirically the impact of different inter-project strategy types on project lead time and engineering hours.

3. Impact of Different Inter-project Strategy Types on Lead Time and Productivity

In this section, we discuss the impact of different inter-project strategy types on lead time and engineering hours. In this part, we again focus on the impact of platform design usage in new product development projects. First, we hypothesize that new car development using platform designs completely new to the firm should require the longest lead time and the largest number of engineering hours (Clark and Fujimoto 1991). Second, we also hypothesize that among the other three strategies including rapid design transfer, sequential design transfer and design modification, rapid design transfer should require the least engineering hours, because rapid design transfer should facilitate effective task sharing and mutual adjustments among engineers.

3-1. Sample Characteristics and Measurements

In order to test these hypotheses, we surveyed 103 project managers of new car and truck development projects: 77 at seven Japanese firms and 26 at three U.S. firms. This questionnaire survey was conducted in the spring of 1992, and most of the projects were completed between 1988 and 1992. Questionnaires were distributed by one central contact at each company to program managers. The actual number of questionnaires distributed to project managers and the selection of projects were decided primarily by those contact persons. The only guideline for consistency was to distribute the questionnaires to at best 15 project managers in each firm.

Inter-project Strategy Type

One question asked whether the platform design each project developed was new to the firm or based on an preexisting or preceding design. New projects that developed their platform design new without any base design were categorized as "new design strategy". New projects based on a platform design of their direct predecessor, which were to be replaced by these new projects, were categorized as "design modification". Those projects based on the platform design of other product lines were categorized as either "rapid design transfer" or "sequential design transfer"[7]. This depended on the answer to a question that asked if there were overlapping and interactions between the new project and the base project, with respect to platform design development. The average time lag between the new project and the base project with respect to market introduction was 15.5 months and 68.8 months for rapid design transfer and sequential design transfer, respectively, which made us believe that this question served to distinguish adequately between these two.

Control Variables

It is always critical to control for differences in project complexity variables to accurately compare lead time and productivity among different projects. First, design complexity and newness are measured by the ratio of new components as opposed to carried over components in two areas separately, body/interior and engine/transmission. In addition to the new component ratio, we also measured innovativeness for each project using a question asking whether technology used in each area of components had technical features new to the firm (yes =1, no =0). The average of the answers in these two areas was calculated to create the innovativeness index, which ranges from 0 to 1. Many components in new product projects are 100 % new without any technically new features, which should be distinguished from components with technology new to the firm. Price in the market and the number of body types for each new product were also measured, and these also significantly affect project performance.[8] Finally, a vehicle-type variable determines whether a project is for a car or a truck, because other design complexity variables do not capture the different nature of design and market for these two kinds of vehicles, and yet the difference potentially has an impact on project performance.

[7] Product variations such as different body types, which are developed within a distinct project, are defined as a single product. In the questionnaire, these "transfers" are clearly defined as those only from other product projects.
[8] Clark and Fujimoto (1991) also used all of these control variables above in their study, and intentionally, no critical measurement in their study is left out in our study.

3-2. Results and Discussion

Table 3 summarizes data on project contents, lead time and engineering hours for each different inter-project strategy type. These projects are mostly major projects, as the average percentage of new design ratio of body and interior components indicates (89%). With respect to inter-project strategy on platform design, 27 projects (26% of the total projects) developed a completely new platform design within the project, while the other projects used existing design or transferred from on-going projects. Among them, 24 projects or 23% of all projects followed the rapid design transfer strategy, in which a platform design was transferred from other projects in progress to their new projects. Twenty-one of the projects among the 24 that followed this strategy were Japanese, which is a much higher proportion of projects than that of the other inter-project strategy types.

Table 3. Data on Project Content and Project Performance

Platform Design	New Design	Rapid Design Transfer	Sequential Design Transfer	Design Modification	Total
# of Projects	27	24	19	33	103
Japanese	19	21	12	26	78
US	8	3	7	7	25
Price ($) **	21,200	15,420	16,580	15,290	17,090
# of Body Types **	1.70	1.50	1.74	2.09	1.79
New Design Ratio (%)					
Engine / Transmission	72	59	59	57	61
Body / Interior	92	92	95	82	89
Innovativeness Index (0-1) ***	0.35	0.29	0.24	0.07	0.23
Lead Time (months) **	60.0	49.5	50.9	49.4	52.5
Engineering Hours * (in millions)	1.89	0.69	2.14	1.95	1.66

Difference statistically significant at: *** 1% Level, ** 5% Level, * 10% Level (One-way ANOVA)
Source: Analysis of survey data.

There are some differences in project contents among different inter-project strategies, which have to be controlled for to compare accurately the impact of the strategy types on project performance. For example, projects for more expensive products tend to have developed more new platform designs than those for less expensive products, as the average price for each strategy type indicates. New projects categorized under design modification strategy, on average, developed more body variations with less technical innovativeness than the other types of projects.

Table 4 lists the regression results for lead time and engineering hours. Engineering hours are converted using a natural logarithm. The first models for lead time and engineering hours use only basic control variables, including nationality, price, and vehicle type, and the second models contain all variables, including project complexity and inter-project strategy types. With respect to lead time, the new design strategy requires by far the longest, and the other three strategies similarly shorten the lead time. On the other hand, while engineering hours for the new design strategy are again larger than the other three inter-project strategies, only new projects using the rapid design transfer strategy require significantly less engineering hours than those using the new design strategy.

Table 4. Regression Analyses for Lead Time and Engineering Hours

Independent Variables	Lead Time (months) 1	Lead Time (months) 2	Engineering Hours ln (million hours) 1	Engineering Hours ln (million hours) 2
Constant	43.38	37.90	13.30	11.14
Nation (US=0, Japan=1)	-5.60 *	-3.94	-1.35 ***	-0.12 ***
Product's Price ($ in thousands)	3.20 *	1.81	0.01	0.01
Vehicle Type (Car=0, Truck=1)	10.26 ***	10.01 ***	0.13	0.23
Project Task Complexity				
Number of Body Types		3.52 *		0.60 ***
New Design Ratio % (Engine / Transmission)		-0.90		0.15
New Design Ratio % (Body / Interior Components)		6.28		1.21 ***
Innovativeness Index (0 - 1)		9.67 **		0.57 *
Inter-project Strategy Type of Platform Design				
1. New Design		-		-
2. Concurrent Design Transfer		-6.76 *		-0.50 **
3. Sequential Design Transfer		-7.24 *		-0.18
4. Design Modification		-7.18 **		-0.05
Adjusted Squared Multiple R	0.16	0.25	0.32	0.59
Sample Size	103	103	76	76

Statistically Significant at: *** 1% Level, ** 5% Level, * 10% Level
Source: Analysis of survey data.

The impact of this savings is significant. If, for example, the average engineer received $25 per hour in salary (excluding benefits), a company using rapid design transfer would save about

$16 million per project, compared to new designs. We should also point out that, as seen in Table 2 in the previous section, new designs correspond to a larger impact on market share growth. However, firms appeared to use rapid design transfers to offer a large number of new products which result in significant revenue increases.

Our interpretation for this result is that in rapid design transfer engineers can efficiently transfer design from a preceding project. Only in this strategy can they appropriately share engineering tasks with engineers in other projects through cooperation, coordination, and mutual adjustments. Our interviews with engineers in these firms supported this interpretation. Some engineers said that transferring an existing design and adjusting it to fit with particular requirements for a new project are difficult. The old design may not have been designed with the consideration of potential transfer to other projects at all. Or, in many cases, it is difficult for engineers in the base project to predict problems a future project may have in transferring the base design.

This discussion is somewhat similar to that of "concurrent engineering" between different functions. Managing overlapping among multiple functions is, in a sense, more difficult than managing overlapping among multiple projects. Multiple functions often have a sequential nature in their tasks. We believe that this partially explains our results that demonstrated a strong advantage of rapid design transfer in project productivity.

One other significant finding exhibited in Table 4 is the different influence of the project task complexity variables on lead time and engineering hours. The innovativeness index greatly affects lead time, while the number of body types and new design ratio of body/interior components strongly influence the required number of engineering hours. Design for additional body types or additional new components may be developed in parallel and where little extra time may be required. These additional tasks necessitate more engineering hours. On the other hand, developing technologies new to the firm requires extra time for idea generation, producing prototypes, and testing, which cannot be done in parallel.

Finally, in contrast with a finding in Clark and Fujimoto (1991), our data suggest that the U.S. firms are not significantly behind Japanese firms with respect to lead time. But there are still great differences in engineering hours. Our interviews with the U.S. engineers suggested that they generally had been targeting a shorter lead time through a cross-functional-team approach, which has resulted in separating each project more than is evident in Japanese projects. A question in our survey revealed that 66% of engineers in the U.S. projects fully dedicated their time to a single project, while only 41% of Japanese engineers did (the difference was statistically significant at the 0.001 level). A project team approach may not be efficient with respect to engineering hours. Engineering task sharing between multiple projects is difficult to implement, while it may be good for shortening the lead time of individual projects.

To sum up: In this section, we discussed data that indicated high productivity achieved by new projects following the rapid design transfer strategy. However, we believe that behind this result, in order to manage concurrent multiple projects, there should be an extensive coordination effort between these projects. In the next section, we will examine the impact of different inter-project types on coordination requirements at the design engineer level.

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 the importance of coordination in a new product development organization, although few studies explored the influence of inter-project interactions on coordination requirements (Allen, 1977; Tushman, 1978; Galbraith, 1982; Clark and Fujimoto, 1991). In this section, we start with the discussion of conceptual frameworks and empirical findings from past studies, even though they do not treat inter-project interactions. They are still necessary as a basis for our later discussions regarding the influence of the inter-project interactions.

In order to increase the quality and quantity of inputs of technical knowledge, a high degree of coordination around technical specialties, including component development 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 generally use a matrix organization to deal with these two types of coordination, as shown in Figure 6. Product development organizations for such 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.

Figure 6. General Matrix-organization Model in Automobile Development

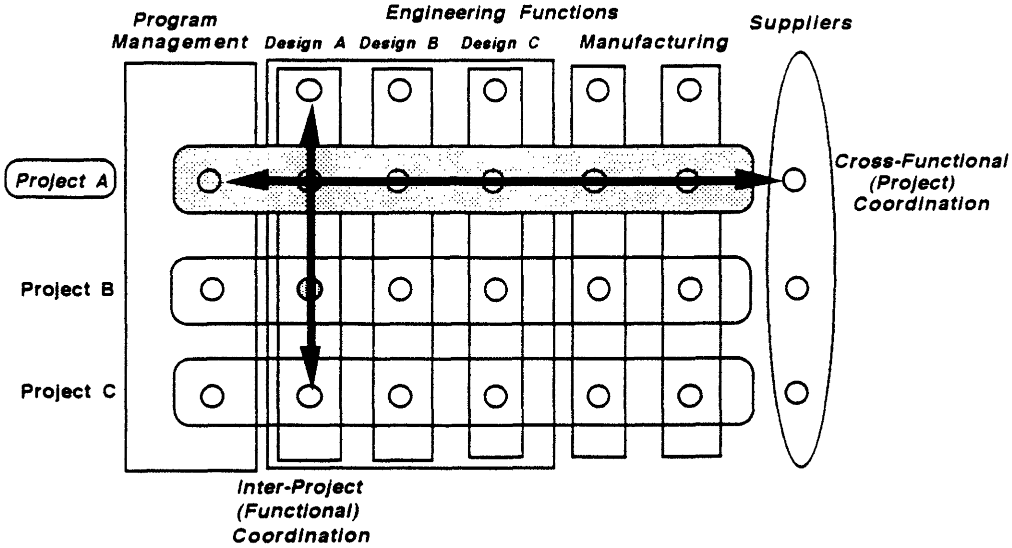
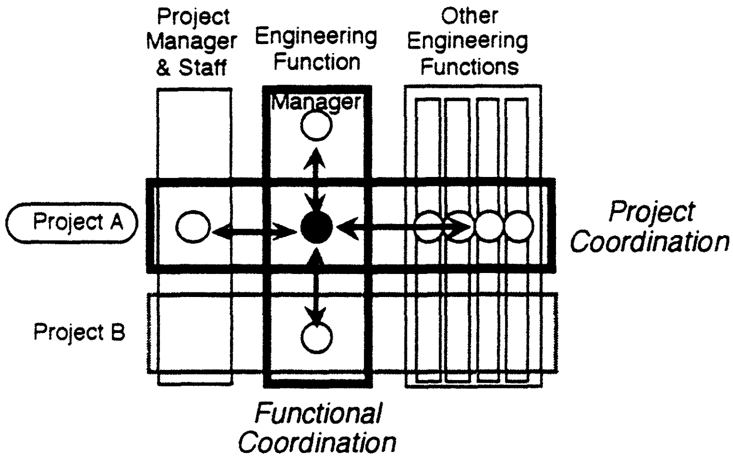


Figure 7 shows a simplified model of such a matrix product development organization, positioning design engineers in an engineering function at the center of the matrix. In this model, the engineers design components primarily for Project A, without direct interdependency with Project B. Even in this model, each design engineer works both for a functional manager, primarily on issues pertaining to technical or component questions, and for a project manager, on issues pertaining to 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 7 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 (including his or 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 7. Matrix Product Development Organization and Definition of "Project Coordination" and "Functional Coordination"



Clark and Fujimoto (1991) used a similar conceptual framework in their study of automobile product development. They 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 38 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 86 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 on the project manager and influence over technical details of the work is centered on the functional manager.

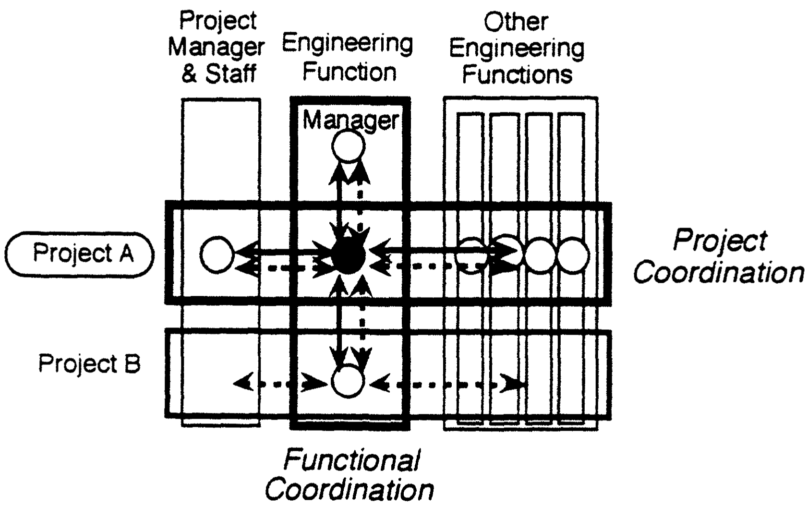
In these empirical studies, project-oriented structures, rather than function-oriented structures, resulted in higher performance, especially in cost and schedule, while in some cases functional orientation was appropriate for technical performance. However, no study has explicitly treated questions 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. 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 coordination 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 8 shows possible influences of inter-project interactions on the degree of organizational coordination, which are indicated by the dotted lines. In this model, the engineer in the new product project develops a design in conjunction with another project, Project B, 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.

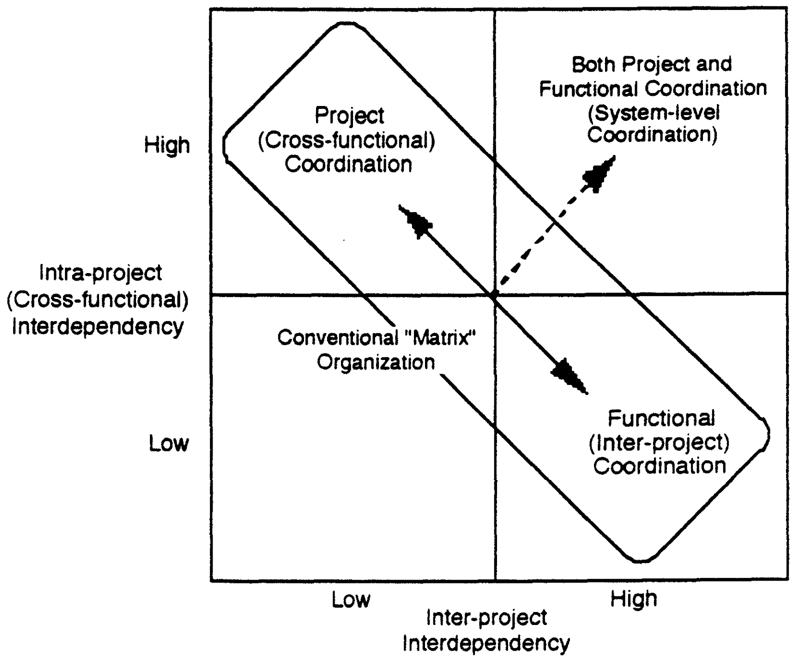
Figure 8. Influence of Inter-project Interactions on the Degree of Coordination Requirements



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 additional cross-functional coordination within that new 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.

A matrix in Figure 9 summarizes the discussion above describing different types of coordination requirements, depending on cross-functional interdependency and inter-project interdependency in a specific component design. When inter-project interdependency is not a critical issue, cross-functional coordination may be most important in component design, and only project coordination may be greatly needed.

Figure 9. Impact of Task Interdependency on Organization



When multiple projects share a technology or design, there is an interdependency between these projects. When a component is not cross-functionally interdependent, the component design can be coordinated between multiple projects within each function. However, because most components are still interdependent with other components, both project and functional coordination may be needed to manage inter-project interactions.

4-3. Sample and Measures

To explore these issues, we conducted a questionnaire survey of design engineers at six Japanese and three U.S. auto manufacturers. Of 220 questionnaires sent to Japanese firms and 90 questionnaires to U.S. firms, 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 one contact 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 on poorly-implemented projects, which we noticed in discussions with them. Because the purpose of this study is not a comparison of performance between U.S. and Japanese firms, we believe that this return rate does not affect the issues probed by this research, although control variables are used to detect possible differences between the two samples.

In the questionnaire, each respondent chose one specific component that he or she worked on for a specific product development project, rather than for 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. The time difference of when the two interacting projects were actually completed in these responses ranged from zero to 28 months and the mean was 9.6 months. Thirteen 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 (% explained by the first principal component = 83%). Performance ratings of design quality and the degree of match with customer needs were averaged to measure design quality performance (% explained by the first principal component = 87%).

Measurements of the Degree of Project and Functional Coordination

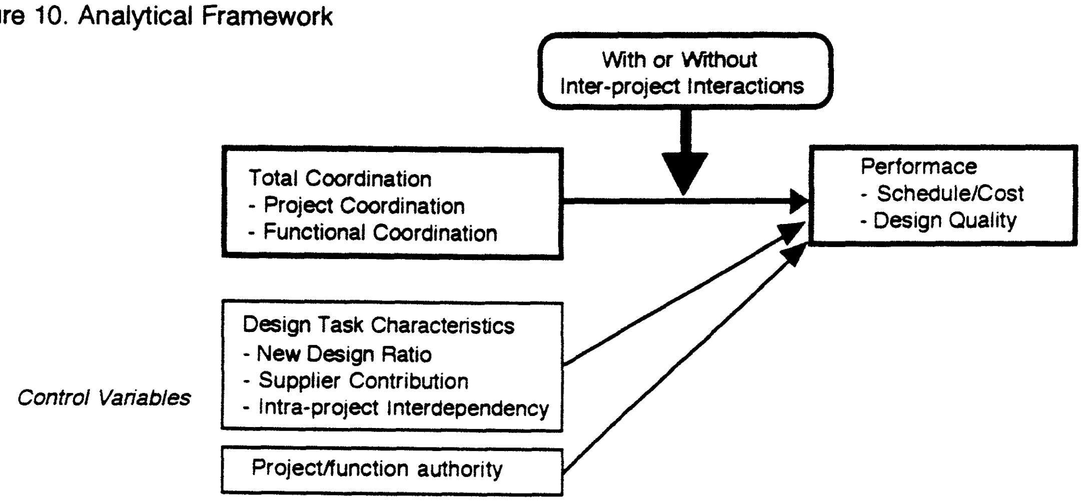
There is not a single best measurement of the degree of coordination. The degree of coordination among different groups, rather than specific means of coordination, needs to be stressed in this particular analysis. The degree of communication has often been used in past studies to measure coordination (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 to measure the degree of integration. This is not a good measurement for 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 their working relationship on the 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 (% explained by the first principal component = 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 (% explained by the first principal component = 86%). The degrees of coordination with a functional manager and with other engineers in the same function were averaged to obtain the functional coordination (% explained by the first principal component = 83%). In addition, we also measured total coordination by averaging the degrees of project coordination and functional coordination (% explained by the first principal component = 96%).

Control Variables

Other project characteristic variables that may affect the relationship between component development performance and organizational coordination are measured as control variables. Figure 10 summarizes the analytical framework that has been explained for this research.

Figure 10. Analytical Framework



First, we asked respondents to estimate the percentage for *each* new component development the component design that was newly designed. On average, 80% of the designs in the component developments with inter-project interactions were newly designed, and 87% of the designs were new in projects without inter-project interactions. Secondly, respondents estimated the percentage of design that suppliers engineered 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, respondents estimated a component's interdependency with other parts of the products by rating, on a 7-point Likert-type scale, the extent the component design affects the other parts of the product. Lastly, respondents were asked to rate the extent of authority regarding design work that the project manager had as opposed to the functional manager.

4-4. Results and Discussion

Descriptive data and a correlation matrix are shown in Table 5 for component developments with inter-project interactions (top half) and those without (bottom half). 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 5. 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 6 shows the regression results for project performance in schedule and cost. The results show that organizational coordination required to perform well significantly differs 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, a project manager's authority contributes significantly to performance only in 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 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 their performance higher than the Japanese respondents. This may have been caused by the low return rate from the U.S. firms, who may have returned surveys only for 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 6. 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 designs regarding the influence of organizational coordination on design quality performance as opposed to schedule/cost performance, as shown in Table 7. 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, a supplier's contribution to the design also has a stronger negative influence on design quality performance in component design with inter-project interactions.

Table 7. 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 8 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 designs without those interactions. The influences of both project coordination and functional coordination are stronger in designs with inter-project interactions. Functional coordination, which directly involves engineers of multiple projects, affects schedule/cost performance only in those designs with inter-project interactions. In addition, project coordination has a stronger influence on performance in designs 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 involvement in design, seems 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 a supplier's involvement more effectively.

Table 8. Summary of the Regression Analyses

		Project (Cross-functional) Cooperation	Functional (Inter-project) Cooperation	Component Inter-dependency	Supplier's Contribution
With Interactions	Schedule/Cost	**	*	**	**/***
	Design Quality		**		*
Without Interactions	Schedule/Cost	*			
	Design Quality		**		

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

To sum up: 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 involvement, tend to cause difficulties to the organization in component design with inter-project interactions.

5. Conclusions and Further Research

The "lean production" paradigm for product development focused mainly on how to maximize performance in one project at a time: how to reduce lead time and total engineering hours by (a) utilizing a project organization with a "heavyweight project manager," who has sufficient authority and resources to marshal a project through each of the marketing and development phases and into manufacturing as quickly as possible; and (b) by managing projects more efficiently and effectively, such as through reducing the time in up-front phases, overlapping as many phases as possible rather than starting them in sequence, subcontracting as much detailed engineering as possible to suppliers, and reducing the percentage of unique components done in-house (Clark and Fujimoto 1991; Womack et al. 1991).

In general, the heavyweight approach of optimizing the performance of individual projects appears to work well as long as companies have constantly growing revenues and many market niches to fill. More specifically, on the positive side, this paradigm has helped firms reduce lead time and engineering costs within individual projects, and improve design quality of individual models, compared to alternative approaches. Alternatives consist primarily of managing development through functional departments rather than through projects, or with a combination of functional departments and projects but with "weak" project managers, who served mainly in a liaison role, coordinating departments.

In the 1990s and foreseeable future, however, company revenues and profits in the auto industry and other industries are falling or flat. In this environment, with severe financial constraints, companies need to optimize not one project at a time but the portfolio of projects and technologies that the company plans to introduce, without overly compromising differentiation among products. More specifically, on the negative side, a project management system that is "too heavy" may make it difficult for projects to cooperate and coordinate with each other, if project managers and engineers have too much independence and try to optimize the performance of their particular projects at the expense of other projects.

To study these issues, this paper first proposed a framework to analyze strategies for multiple new-product development projects by developing an inter-project strategy typology. In section 2, using this framework and data on 211 new products at 17 worldwide auto manufacturers, we argued that high performers measured by market share growth more often utilized a rapid design transfer strategy. Through the rapid design transfer strategy, new technologies and designs developed in one project are quickly transferred to other projects within the firm. This result supported our proposition that, by managing inter-project interactions effectively, rapid design transfer is theoretically the most effective way both to develop multiple products quickly and to maintain relatively new designs in these products with limited financial and organizational resources.

In section 3, we found that the rapid design transfer strategy may be the most efficient strategy with respect to engineering hours. Only through this strategy can a preceding design be transferred from a base project to a new project with effective task sharing among engineers and mutual adjustments between the two projects.

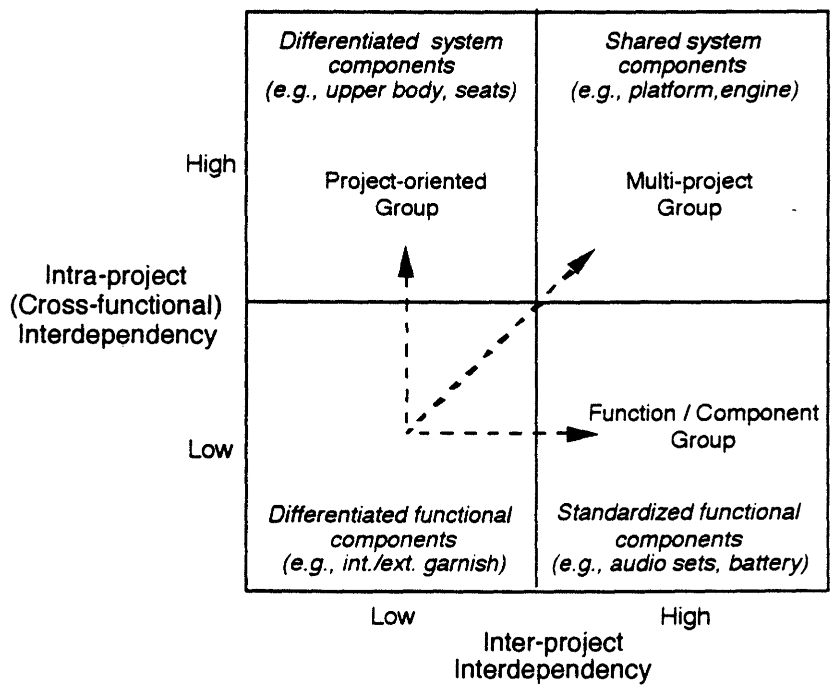
Section 4 examined how organizational requirements differ for component designs with and without inter-project interactions. The questionnaire survey of 215 component engineers provided evidence that organizational coordination required to manage these two types of component design - with and without 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 involvement. This result theoretically suggests 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 offer a competitive advantage in the market on the presumption that firms have limited financial and engineering resources. In addition, 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, while maintaining a project integrity for individual 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 their effective implementation 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 11 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, the group designation 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, which also need to vary with each product to make it distinctive. These types of components, which we call *differentiated system components*, need to be well managed through a project-oriented group.

Figure 11. Design Interdependency and Organizational Coordination

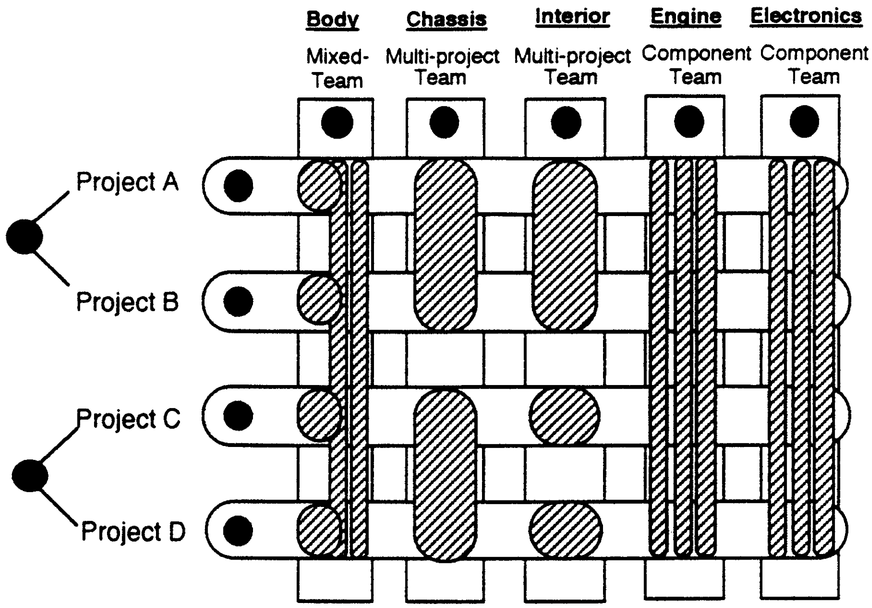


On the other hand, there are some components for which the benefits of differentiation in the market are relatively small. For example, firms do not extensively differentiate audio systems or batteries for each different product and may want to standardize these designs among different projects. This 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 or component group. 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. In shared system components, either a project-oriented group or a component group is not sufficient.

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 a simple matrix organization does not seem to be adequate, there may have to be extensively differentiated mechanisms within a matrix organization.

In our interviews, we found that some Japanese firms have been following this idea. Figure 12 depicts an example of a *differentiated matrix* from a Japanese firm. Depending on the nature of the interdependency, they were flexible about changing task partitioning and the organizational structure. For example, components like batteries and audio systems in the electronics design division tend to be developed by a pure component group, while platform components are developed by a multi-project *platform team*. Engineers working on some body components are totally devoted to a project through a project-oriented group. Because the nature of both cross-functional and inter-project interdependencies changes all the time depending on the combination of projects being developed and their strategies, they should change this structure quickly. We plan to explore for this concept of a "dynamic" differentiated matrix structure both empirically and theoretically.

Figure 12. An Example of Differentiated Matrix Organization



The second question is how firms can manage the development of *shared system components*, which cannot be coordinated by either traditional project-oriented or function-oriented groups, 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 analyze 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.

In conclusion, our research suggests that a new paradigm for project management must look for a greater *balance* between what is optimal for individual projects and what is optimal for the firm overall, at least in the case of firms that seek a greater mix of efficiency and profitability with design quality and market growth. We believe, furthermore, that this search for balance requires a *multi-project management* perspective. Companies may still prefer to use a version of relatively heavyweight project managers and project-management systems, compared to pure functional organizations. But firms appear to be moving toward greater coordination and sharing of technologies and design knowledge across projects by focusing on the evolution of component systems and using more differentiated types of matrices --some components development organized as a project team and customized for an individual model, and other components development organized by functions or multi-project teams, depending on the level of sharing across projects. This approach maximizes the distinctiveness of product components visible to the customer or essential to differentiate one product from another, but also reduces development time and costs as well as manufacturing preparations by sharing as many components as possible.

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Appendix 1. Change Index of Platform Design

<u>Change in Wheelbase and Treads</u>

Points

- 0: Both wheelbase and tread are the same
- 1: Only either wheelbase or tread are new
- 2: Both wheelbase and tread are new

<u>Change in Suspension Design</u>

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.