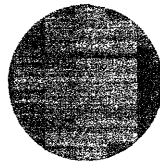


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**MULTI-PROJECT STRATEGY, DESIGN TRANSFER
AND PROJECT PERFORMANCE: A SURVEY
OF AUTOMOBILE DEVELOPMENT PROJECTS
IN THE U.S. AND JAPAN**

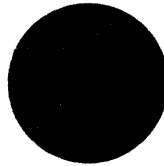
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Abstract

Large manufacturers usually need to manage multiple projects in order to leverage their financial and engineering resource investments on new technologies and designs. The purpose of this paper is to explore the relationship between different multi-project strategies and project performances measured by lead time and engineering hours. The multi-project strategy in this study focuses on different ways of transferring core technologies and designs from one project to another within the firm. First, this paper proposes a typology of different multi-project strategies, which categorizes new product development projects into four types: *new design*, *rapid design transfer*, *sequential design transfer*, and *design modification*. Second, using our survey results on 103 different new product projects at 10 automobile firms in Japan and the U.S., this study concludes that projects using the rapid design transfer strategy are the most efficient in terms of engineering hours. Only through rapid design transfer 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. This paper also discusses organizational requirements for managing rapid design transfer projects. Neither a pure project-team approach nor a functional approach seem appropriate for the management of concurrent multiple projects.

1 Introduction

In many industries, large manufacturers have at least several product lines and constantly undertake multiple development projects to add new product lines or to improve and replace existing products. In order to achieve economies of scale and scope, firms may want to leverage their financial and engineering resource investments on new technologies and designs. These firms need to systematically manage these multiple projects in addition to individual projects. Specifically, technologies and designs developed in one project are often reused or transferred to other projects within the firm. Therefore, each new product development project often has both technological and organizational linkages or interdependencies with other past or on-going projects. The strategic management of these linkages among multiple projects is complicated but is often a critical issue for a firm's product-development performance. However, there has been little empirical research that systematically explores the complicated inter-project technology transfers within a firm and their impact on project performance. The purpose of this study is to explore product-development strategy with respect to core-design transfers among multiple projects and their impact on project performance including lead time and productivity.

Since the management of new product development has become a central issue in global competition, a number of studies have focused on the speed and the productivity of individual projects (Cohen, et al. 1979; Quinn and Mueller 1982; Imai et al., 1985; Gold, 1987; Gomory 1989; Gupta and Wilemon, 1990; Womack et al., 1990; Clark and Fujimoto, 1991; Cusumano, 1991; Cordero, 1991; McDonough III and Barczak, 1991; von Braun, 1991; Leonard-Barton and Sinha 1991; Crawford, 1992). One common finding across these studies is that, in order to shorten the development lead time and to achieve high productivity, a relatively project-oriented organization with strong cross-functional coordination is essential. Each project in this approach is relatively independent of other projects within the firm, and strong project managers facilitate quick completion of a project by integrating different functions within the project (Clark and Fujimoto, 1991). But even though this approach has led to successful individual projects, it may not necessarily be efficient for managing linkages among multiple projects.

High levels of engineering productivity in individual projects alone may or may not contribute to making a firm more effective in product development. But different ways to manage multiple new product development projects such as by taking repeated advantage of designs and components in more than one product may boost the effectiveness and the efficiency of the entire firm. Rapid transfers of technologies and designs from one project to others may thus increase the speed of completing multiple projects and may decrease component costs for individual projects through inter-project synergies. In short, the project-team approach alone has not provided insights into the management of the entire project portfolio within the firm. Because of

increasingly intense international competition, the perspective of multi-project management has become a critical issue for competition (Fujimoto et al., 1992; Meyer and Utterback, 1993).

The strategic management of specific inter-project linkages must account for more dimensions than the simple distinction between radical innovation (i.e., a technology new to the firm) and incremental change (i.e., the migration of technology existing within the firm), discussed in a relatively large number of past studies (Dewar and Dutton, 1986; Ettlie, et al., 1984). Some academic researchers have emphasized the strategic importance of planning for and managing the evolution of a sequence of new product projects (Hayes, et al., 1988; Wheelwright and Sasser, 1989; Meyer and Utterback, 1993). Wheelwright and Sasser (1989) have discussed the importance of the effective strategic management of a core product with a distinctive platform and its derivative projects. (Similar discussions are also seen in Hayes, et al., 1988 and Wheelwright and Clark, 1992). They have discussed this strategic issue by suggesting a framework known as the product generation map. Meyer and Utterback (1993) have also discussed the management of product families. They emphasized the importance of planning and managing the evolution of a portfolio of products, focusing on the development and application of a firm's core technology. The concepts of managing the product generation map and the product family are related to the multi-project strategy discussed in this study. However, these researchers have not yet empirically examined the relationship between different strategies explained by these frameworks and project performance.

In the next section, we propose a typology of different types of multi-project strategies. Section 3 hypothesizes the relationship between these strategies and project performance measured by lead time and engineering hours. After we discuss the sample and measurements for the questionnaire survey in Section 4, Section 5 provides an evidence that one type of multi-project strategy has a significant advantage in engineering hours. Section 6 discusses strategic and organizational implications from the survey results.

2 A Framework: A Typology of Multi-Project Strategy

A framework for multi-project strategy in this study considers two different types of linkages between multiple projects: the linkages between different product lines (inter-product-line linkage) and the linkages between past and present projects (evolutional linkage). For example, some projects may use the core technology of a previous generation of the same product line, and others may transfer and use the core technology from other product lines within the firm. This study refers to both cases as design transfers between multiple projects. On the other hand, some other projects may choose to develop a new technology from scratch without using either type of design transfer.

Covering these aspects of design transfers, Figure 1 proposes a multi-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 the timing of design transfer. This typology covers all types of new product development projects, and these four types are mutually exclusive.

For the analysis in this paper, we focus on the design transfer of the vehicle platform as a core design in new car development projects. However, the same framework can be applied to major components of most system products. A platform primarily consists of floor panels, a suspension system, a firewall and rocker panels. It defines the architecture of the automobile because the platform significantly affects the basic characteristics of the rest of the vehicle's components including the body structure, drive-train type and engine/transmission size. Platform design, from this perspective, is considered to be a "core" sub-system. This notion of the platform as the core sub-system of the automobile is widely shared by people in the industry, as well as by researchers studying the industry. The selection of a specific platform design determines the general level of design functionality and sophistication of the entire product. In addition, platform technology is one of the key areas in which most automobile manufacturers compete as they introduce newer designs and a higher level of performance. Not surprisingly, more financial and engineering resources are required to develop a new platform design than most other components.

The extent of change required in a new project determines whether its core design (e.g., platform design) is newly developed or transferred and modified from other projects within the firm. New product projects that develop their platforms from scratch without a preexisting base design are categorized as the first type of the four, *new design strategy*. This distinction between new design and the other three types is conceptually similar to the traditional categorization of radical versus incremental innovation (Dewar and Dutton, 1986; Ettlie, et al., 1984; Kleinschmidt and Cooper, 1991). In this framework, incremental changes are broken down into three types, depending on the location of the base design source and transfer timing: 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. Thus, the typology has four multi-project strategy types, including the new design strategy and three variations of the design transfer strategy.

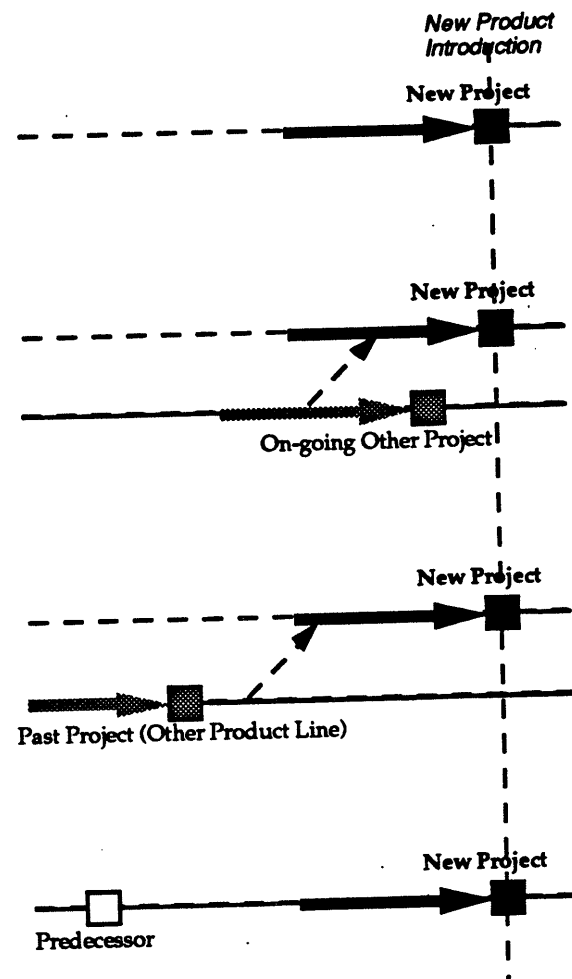
Figure 1 Typology of the Project Strategy

Type 1: New Design

Type 2: Rapid Design Transfer

Type 3: Sequential Design Transfer

Type 4: Design Modification



In the first type, *new design*, there is relatively low technological relatedness to or interaction with other projects within the firm. Members of the new design project concentrate on creating a new technology and design. While the project's engineering task requirements may be the highest among the four because the core design is new and few components are shared with other projects including its direct predecessor, both coordination costs with other projects and design constraints may be low. This type of project is appropriate to incorporate the latest technology and design into the new product without many restrictions.

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 has completed its design engineering. In these two projects, the new project and the base project, mutual adjustments are possible and perhaps likely, because the development efforts overlap chronologically.

The third type, *sequential design transfer*, transfers a design from a base model to a new model after the base model's development is finished. This type of project basically reuses an existing design that is "off-the-shelf." It may not be efficient or effective, compared to rapid design transfer, because concurrent design task sharing and mutual adjustments are not possible¹. In addition, when a new project uses the core design in this manner the design being transferred is already relatively old compared to designs transferred as a base model is being developed, as in rapid design transfer. Design constraints may also be high because this strategy may force the new project to accommodate elements of the base core design from another product line.

The last type, *design modification*, refers to a new product project that develops a core design directly based on that of a predecessor product. This type of project may also have to consider constraints from the core design of the predecessor product (i.e., the current model). The difference between the design modification and the sequential design transfer is only the source of the base design and its application. 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. Design modifications may be technically easier than a sequential design transfer, which transfers a core design between different product lines. Another difference by definition is that sequential design transfer can be used to add a new product line, while a design modification is only for replacement projects.

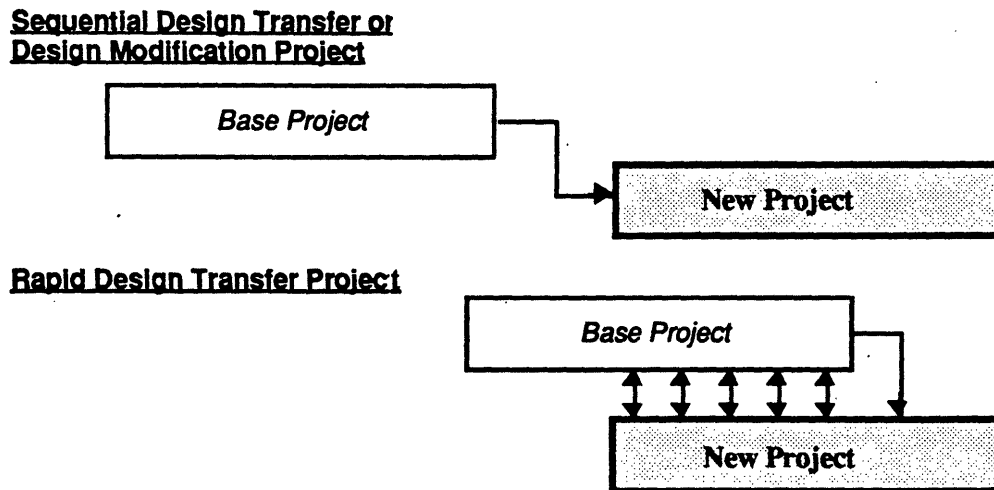
3 Hypotheses on Lead Time and Productivity

In this section, we discuss the potential impact of different multi-project strategy types on new product development lead time and engineering hours. We will again focus on the impact of platform design usage on new product development projects. When we began this study, first, we hypothesized 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). Developing a new platform requires time and engineering resources in all areas including drawing, prototype testing, and process engineering. In addition, because the platform design is a core sub-system of the automobile, a new platform often requires new or extensively modified components among the other primary vehicle components including body structure and drive train, as well as new linking technologies between these components (Rosenberg, 1982; Henderson and Clark, 1991; Iansiti, 1993).

¹ This discussion of hypothetical differences between rapid and sequential design transfer is 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.

Second, we hypothesized that among the other three multi-project strategies of rapid design transfer, sequential design transfer and design modification, rapid design transfer may require the least engineering hours, because this strategy should facilitate effective task sharing and mutual adjustments among engineers, as shown in Figure 2. Conceptually related to this discussion, numerous studies have provided evidence that mutual adjustments lead to greater efficiency and effectiveness in transferring technology from upstream functions to downstream functions (e.g., Cohen, et al. 1979, Quinn and Mueller 1982; Imai, et al., 1985; Leonard-Barton, 1988; Gomory 1989; Leonard-Barton and Sinha 1991; Tyre, 1991; Clark and Fujimoto, 1991). These studies have also argued that mutual adjustments are most effectively and efficiently implemented when there are overlapping and intensive communications among multiple functions. The same concept may be applied to the case of the interface among multiple projects. Even when a new car project uses a preceding or an existing platform design as a base, it develops new proprietary components for other parts of the new car's design, such as the exterior body. Linking technologies between the platform design and other components are complicated. It is predictable that many potential problems are only identified after the new car project starts. Without any overlaps among the base project and the new project, it is impossible to adjust the base platform design, so that the new project can avoid these problems.

Figure 2 A Framework for Different Modes of Design Transfer



Transferring and reusing an old design in a new project may not be efficient, particularly when engineers apply the old design in developing the new project in ways that cannot properly target new market competition and new customer needs. For example, Cusumano (1991) has argued that reusing existing designs in new software development without appropriate planning may have a

negative impact on development productivity and quality. When there is a long time lag between a base project and a new project that transfers a design from the base project, it is less likely that there are specific plans for this design transfer during the base project.

4 Sample Characteristics and Measurements

In order to explore these questions, we surveyed 103 project managers of new car and truck development projects: 78 at seven Japanese firms and 25 at three U.S. firms. This questionnaire survey was conducted in the spring of 1992, and most of the projects were completed between 1986 and 1992. Questionnaires were distributed by one central contact at each company to project managers. The actual number of questionnaires distributed and the selection of projects were decided primarily by those contact persons. The only guideline for consistency was to distribute the questionnaires to at most 15 project managers in each firm who had recently worked on relatively large new product projects. The sample did end up including some variations in project contents that will be discussed later. In the questionnaire, product variations such as different body types and trim levels which are developed within a distinct project are defined as a single product. Questionnaires were pre-tested with three project managers. In particular, we discussed with several project managers and engineers the definitions and measurements of lead time and engineering hours which are described in Appendix 1. Throughout our research project, including our data analysis stage, we conducted in-depth interviews with approximately 130 engineers and 30 new product project managers at five Japanese, three U.S., and four European firms between September 1991 and May 1993².

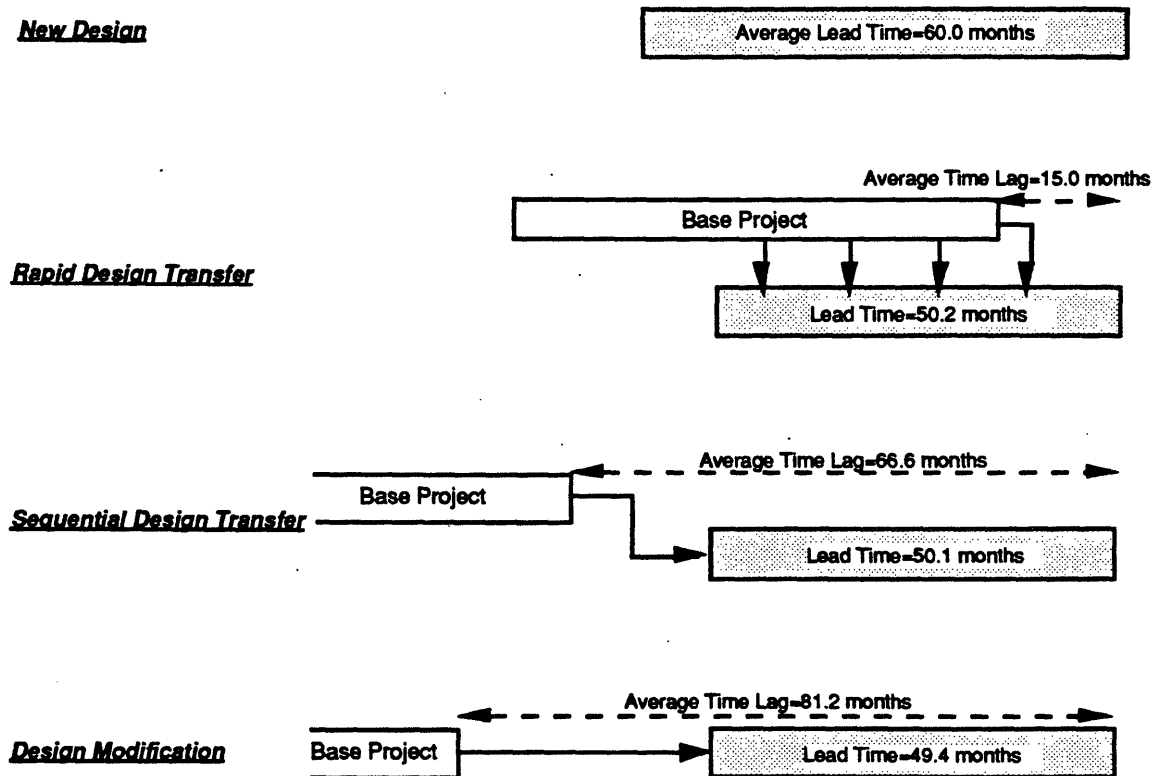
Project Strategy Type

One survey question asked whether the platform design each project developed was new to the firm or based on a preceding design. New projects that developed their platform design without any base design were categorized as following the "new design" strategy. New projects based on a platform design of their direct predecessors, which were to be replaced by these new projects, were categorized as "design modifications". Those projects based on the platform design of other product lines were categorized as either "rapid design transfer" or "sequential design transfer". The determination of which category depended on the answer to a question that asked if there were overlaps and interactions between the new project and the base project with respect to platform design development. Additionally, a project meets the definition of a transfer only if the managers of the base project and the new project are different.

² Our field study included three trips to Japan, one to Europe, and several to Detroit, augmented by numerous interviews around Boston with MIT's International Motor Vehicle Program participants.

The average time lag between the new project and the base project with respect to market introduction was, as shown in Figure 3, 15.0 months for rapid design transfer and 66.6 months for sequential design transfer. The difference in lags made us believe that this question served to distinguish adequately between these two (see Appendix 2 for complete distributions of the time lag associated with each strategy). At 81.2 months, the average time lag for projects using the design of one of their direct predecessors, the design modification strategy, is even longer than that of sequential design transfer projects.

Figure 3 Multi-project strategy and Average Design Transfer Time Lag



Project Content and Control Variables

It is always critically important to control for differences in project complexity in order to accurately compare lead time and productivity across different projects. First, design complexity and newness are measured by the ratio of new components versus carried over components in two separate areas, body/interior and engine/transmission. The automobile design consists of three primary component groups: body/interior, engine/transmission, and platform. Therefore, these new

component ratio variables cover the rest of the automobile design not contained within the platform. Second, many components in new product projects are completely new yet do not impart any new technical features, and should be distinguished from components that incorporate technology new to the firm. Therefore, in addition to the new component ratio, we also measured the innovativeness of each project by asking whether the technology used in each component area brought new technical features to the firm (yes =1, no =0). The average of the answers in these two areas was calculated to create an innovativeness index, which ranges from 0 to 1. Third, price in the market and the number of body types for each new product were also measured, because these may also significantly affect project complexity.³ Finally, a vehicle type variable denotes whether a project is for a car or a truck, because the other design complexity variables used did not capture the different design and market characteristics for these two kinds of vehicles. We felt that such differences might potentially have an impact on project performance.

5 Survey Results

Lead Time and Engineering Hours

Table 1 summarizes the raw data on project content, lead time and engineering hours for each different multi-project strategy type. The set of projects studied are, in general, relatively major projects as opposed to minor facelift projects, as indicated by the average percentage of new design ratio for body and interior components (89%).

With respect to multi-project strategy applied to platform design, 27 of 103 projects (26% of all projects) were developed as completely new platform designs within their projects, while the other projects used existing designs or transfers from on-going projects. Among the remaining 76 projects, 23 projects or 22% of all projects followed the rapid design transfer strategy, in which a platform design was transferred from other projects in progress to the new projects. Twenty of the 23 rapid design transfer strategy projects were Japanese, which is a much higher proportion of projects than that of the other multi-project strategy types. Twenty of 103 projects or 19% of all projects followed the sequential design transfer strategy and 33 projects or 32% were design modification projects. The average project time lag for each multi-project strategy is presented in Figure 3.

³ Clark and Fujimoto (1991) also used all of these control variables in their study. Our study intentionally uses their set of variables for product characteristics.

Table 1 Data on Project Content and Project Performance⁴

Platform Design	New Design	Rapid Design Transfer	Sequential Design Transfer	Design Modification	Total
# of Projects	27	23	20	33	103
Japanese	19	20	13	26	78
US	8	3	7	7	25
Price (\$) **	21200 (8860)	15540 (7610)	16380 (7720)	15290 (7220)	17090 (8100)
# of Body Types **	1.7 (0.6)	1.6 (0.5)	1.7 (0.8)	2.1 (0.9)	1.8 (0.7)
Truck/Van	7	5	3	8	23
New Design Ratio (%)					
Engine / Transmission	72 (32)	57 (40)	61 (35)	58 (36)	61 (36)
Body / Interior	92 (20)	91 (20)	95 (12)	82 (31)	89 (23)
Innovativeness Index (0-1) ***	0.35 (0.33)	0.30 (0.36)	0.23 (0.30)	0.07 (0.18)	0.23 (0.31)
Lead Time (months) **	60.0 (15.6)	50.1 (11.9)	50.1 (12.4)	49.4 (14.9)	52.5 (14.5)
Engineering Hours (million hours)	1.89 (1.60)	0.72 (0.48)	2.02 (2.55)	1.95 (2.03)	1.66 (1.87)

Difference statistically significant at: *** 1% Level, ** 5% Level, * 10% Level (One-way ANOVA)
Standard deviations are in parenthesis.

There are some differences in project content among the different multi-project strategies which have to be controlled for to accurately compare the impact of the strategy type on project performance. For example, new platform designs tend to be developed more often for more expensive products than for less expensive products, as the average price for each strategy type indicates. At \$21,200 the average price for a new-design-strategy project is much higher than that of other types. Less expensive products may be more cost-constrained and may use more existing components. A new design strategy in the platform tends to be associated with more new components in the engine and transmission designs. Because of the system nature of automobile design, a new platform design, which is a core sub-system, may necessitate more new component designs in the rest of the vehicle's design. In addition, projects utilizing a new design strategy for the platform tend to focus on technical innovation and design quality as opposed to product costs, as shown later in this section. This difference in objectives for new product development projects may be another reason why new-design-strategy projects develop more new engine and transmission components.

New projects categorized under the design modification strategy, on average, developed more body variations and offered less technical innovation than the other types of projects. It is easily

⁴ We were able to collect engineering hour data for only 76 projects among the total sample of 103 projects. The data summary for the 76 projects shown in Appendix 3 is not significantly different from the data in the total sample.

observed that established "bread-and-butter" product lines such as the Sentra or the Corolla tend to have a large number of body variations and also frequently use the design modification strategy. On the other hand, the number of body types for rapid design transfer projects tends to be small. This may be because a project following the rapid design transfer strategy tends to be a derivative product.

Table 2 lists the regression results for lead time and engineering hours. Engineering hours are converted using a natural logarithm⁵. Model 1 for lead time and engineering hours uses only basic control variables, including nationality, price, and vehicle type. Model 2 and Model 3 contain all important variables, including those for project complexity and multi-project strategy types. Model 1 for lead time shows that more expensive products and trucks tend to require more time. Japanese projects tend to be shorter than the U.S. projects. Model 2, which introduces the multi-project strategy variables, shows that the new design strategy requires by far the longest lead time, and the other three strategies similarly shorten the lead time. Nationality and price factors disappear when the multi-project strategy variables are included.

⁵ We obtained a residual plot for predicted values from a trial regression analysis using unadjusted engineering hours as a dependent variable and independent variables in Model 2 of Table 2. The plot indicated that the engineering hours should be adjusted by logarithm. Specifically, many residuals showed minuses in the middle of the predicted values and large positive numbers for the high predicted values. The standard deviation for engineering hours, which is even bigger than the average, is also a crude indicator of the need for adjustments.

Table 2 Regression Analyses for Lead Time and Engineering Hours

Independent Variables	Lead Time (months)		Engineering Hours In (million hours) (Supplier Adjusted)		
	Model 1	Model 2	Model 1	Model 2	Model 3
Constant	43.38	37.74	13.30	11.27	11.56
Nation (US=1, Japan=0)	5.60 *	3.67	1.35 ***	1.13 ***	1.16 ***
Product's Price (\$ in ten thousands)	3.20 *	1.81	0.01	0.00	0.02
Vehicle Type (Car=0, Truck=1)	10.26	10.01 ***	0.13	0.25	0.20
Project Task Complexity					
Number of Body Types		3.76 **		0.57 ***	0.59 ***
New Design Ratio % (Engine / Transmission)		-1.40		0.10	0.00
New Design Ratio % (Body / Interior)		6.30		1.20 ***	1.30 ***
Innovativeness Index (0 - 1)		10.10 **		0.65 **	0.68 **
Inter-project Strategy Type of Platform Design					
1. New Design		-		-	-
2. Rapid Design Transfer		-6.99 *		-0.55 **	-0.60 **
3. Sequential Design Transfer		-7.22 *		-0.18	-0.18
4. Design Modification		-7.36 **		-0.06	-0.08
Adjusted Squared Multiple R	0.16	0.25	0.32	0.58	0.57
Sample Size	103	103	76	76	76

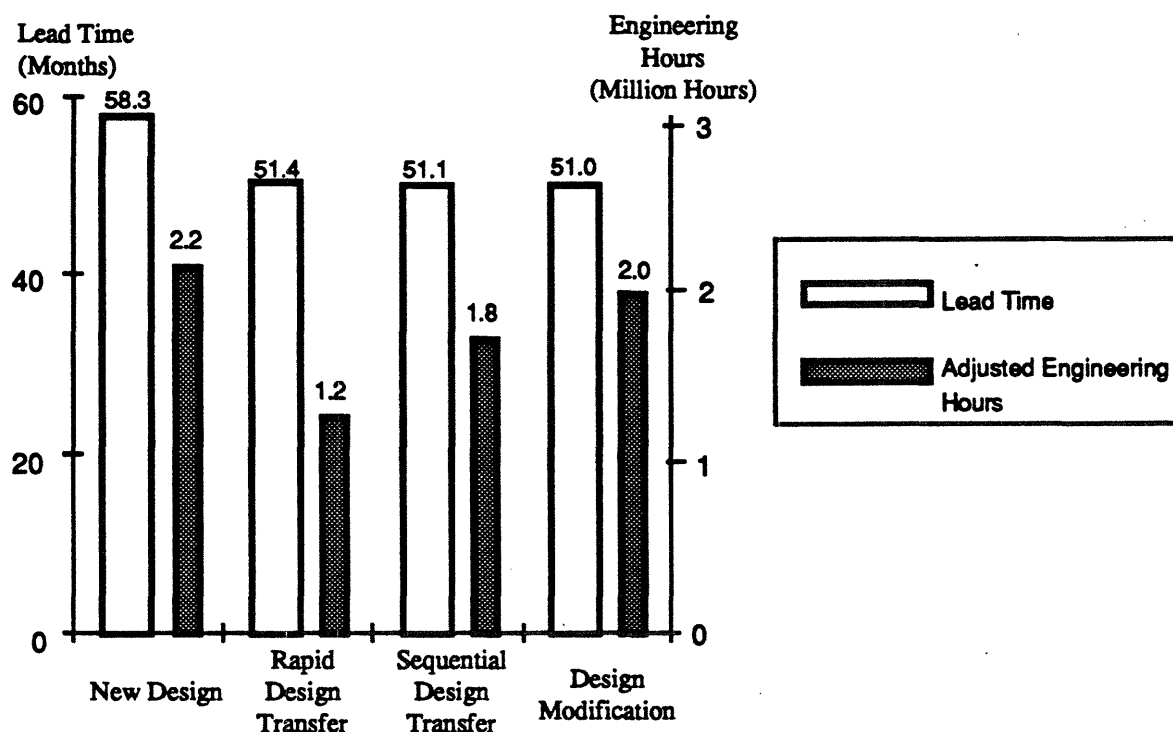
Statistically Significant at: * 10% Level, ** 5% Level, *** 1% Level

With respect to engineering hours, in Model 1 with only control variables, Japanese projects require far fewer hours, but product price or vehicle type does not have an influence. In Model 2, engineering hours for the new design strategy are again larger than the other three multi-project strategies. However, in marked contrast with the results regarding lead time, among new product projects following the three multi-project strategies, only new projects using the rapid design transfer strategy require significantly fewer engineering hours than those using the new design strategy⁶.

In order to visually compare lead time and engineering hours among the four multi-project strategies, Figure 4 illustrates adjusted results from the regression analyses in Table 2. This adjustment scheme used the average numbers for all independent variables in Appendix 3 (product price=\$17,300, # of body types=1.8, engine/transmission new component ratio=62%, body/interior new component ratio=90%, innovativeness index = 0.23) except for the country and vehicle-type dummy variables (=U.S. passenger car projects).

⁶ This result does not change when engineering hours are adjusted for supplier contribution in design to include engineering hours for both internal and external tasks (See Appendix 1 for the adjustment method).

Figure 4 Comparisons in Adjusted Lead Time and Engineering Hours



Although the adjusted scheme shown above is statistically appropriate, it may not be totally realistic in depicting actual product development projects. For example, the adjusted engineering hours for design-modification projects are close to those for new-design projects. However, as shown in Table 1, a new design strategy for the platform tends to be associated with more new designs and technologies in the engine/transmission and the body/interior components. On the other hand, new product development following the design modification strategy does not usually introduce many new technologies or designs. Therefore, we also calculated adjusted numbers that use the average values of the new component ratios and the innovativeness index for each strategy, while still using the average of the total sample for other independent variables (see Nobeoka, 1993 for actual data). In this adjustment scheme, new-design projects require far more engineering hours than the other strategies.

Because the engineering hour data were collected for only the rapid design transfer projects, and not the combination of a given rapid design transfer project and its preceding base project, there may be questions regarding negative impacts to the base project. If these impacts are severe enough, the usefulness of the rapid design transfer strategy might become suspect. In order to test this criticism, a question in the survey asked whether there was another concurrent project with which the respondent's project shared the platform design, and had significant overlap and interaction. The results showed that these concurrent projects (i.e., other rapid design transfer

projects) did not significantly add engineering hours to the respondent's projects (see Nobeoka, 1993 for the actual analysis). This leads us to believe that a rapid design transfer project would not significantly impede a preceding base project.

Other Important Findings on Lead Time and Engineering Hours

Other significant findings exhibited in the regression analyses in Table 2 include the influences of the project task complexity variables upon lead time and engineering hours. First, the number of body types and the new design ratio of body/interior components only have a strong influence on the required number of engineering hours, not on lead time, while the innovativeness index greatly affects both lead time and engineering hours. Design for additional body types or additional new components may be developed in parallel and may require little extra time. Therefore, these additional tasks necessitate more engineering hours, but not additional lead time as long as variations are designed in parallel. Developing technologies new to the firm requires extra time for idea generation, producing prototypes, and testing, which cannot be done completely in parallel. New technologies tend to require new manufacturing equipment, which cannot be done completely in parallel either. Therefore, developing more new components that incorporate technological features new to the firm requires both a longer lead time and more engineering hours.

Secondly, trucks are associated with a longer lead time than cars, although there is no significant difference in engineering hours. For example, product life cycles for cars at Japanese firms are, on average, about four or five years, while those of trucks are generally eight years or more. This difference primarily reflects variations in the competition and the nature of each market. A program manager for a truck program at a Japanese firm in our interview explained that it is not necessary to shorten the lead time of trucks as much as that of cars, and this is one of the reasons why the lead time for truck projects tends to be longer than those for cars. In other words, this data may support the idea that lead time is affected not only by organizational capabilities but also by the nature of the market.

One other important finding in Table 2 is in contrast with a finding in Clark and Fujimoto (1991). Our data suggest that, after controlling for all variables for project characteristics, the U.S. firms are not significantly behind Japanese firms with respect to lead time, although there are still great differences in engineering hours. We attribute the difference between the two studies to improvements at U.S. firms and the difference in the timing of projects. The data in the Clark and Fujimoto study comes from projects in the mid-1980s, while the project data presented here was generated between the late 1980s and early 1990s.

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 a greater separation between projects than is evident in Japanese firms. A question in our survey revealed

that, on average, 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, though it may be good for shortening the lead time of individual projects. In our field studies, we found that at two of the three U.S. firms, managers have internally argued about the advantages and disadvantages of the project-team approach and co-location of engineers.

6 Discussions on "Rapid Design Transfer"

This section discusses some implications of the survey results on the rapid design transfer strategy. First, we suggest potential reasons for the productivity advantages of this strategy, based on our extensive interviews with project managers and engineers. Then we discuss organizational requirements to manage rapid design transfer projects, which include particular communication patterns for project managers and a strong control above project managers, respectively.

6-1 Efficient Multi-Project Management: Rapid Design Transfer

There are at least several reasons why fewer engineering hours are required to develop a project using a rapid design transfer strategy than other multi-project strategies, including the other design transfer strategies⁷. In a rapid design transfer, engineers can transfer a design from a preceding base project to a new project more efficiently than in sequential design transfer or design modification projects. There are two basic factors that may contribute to this difference. First, the time lag between completion of a base project and that of a new project is much shorter in a rapid design transfer project than the other two types of transfer strategies. Second, there is overlap between a preceding base project and the new project only in the rapid design transfer strategy. These two factors create specific advantages and disadvantages in productivity for each multi-project strategy. The first factor, the time lag between completion of a base project and that of a new project, may affect the difficulty of advanced planning and of incorporating old designs into a new design architecture. The second factor, overlap between a preceding base project and a new project, may have an influence on the feasibility and the efficiency of inter-project communication. These issues are categorized into the following five areas: (1) *advanced planning*, (2) *mutual adjustments, task sharing, and joint design*, (3) *transfer of a "fresh" design vs. "dated" design*, (4) *problems of "anonymous" design*, and (5) *role of a general manager for multi-project management*.

⁷ Program managers and engineers we interviewed basically agreed with our interpretations. However, some of the following interpretations are still only hypotheses that should be studied further in detail.

(1) Advanced Planning

When a new project transfers and uses a platform from a preceeding project, the new project usually needs to modify the base platform design to adjust it to the new project's proprietary architecture. The difference in design requirements for the platform design between the two projects may be caused by many factors, such as different customer needs. In addition, linking technologies between the platform and other components of the automobile design such as the exterior body are often different between the base product and the new product. Because body designs are usually different between the two products, this difference alone often requires adjustments to the base platform design.

It may be more efficient if advanced plans are made during the base project regarding how a future project might use the base project's platform design. The time lag between a base project and rapid design transfer project is much shorter than that between a base project and other transfer strategies, as shown in Figure 3. The time lag between the base project and the new project is long in sequential design transfer and in design modification, at 66.6 months and 81.2 months, respectively. These long time lags may reflect circumstances in which the base platform was designed without any plans or considerations for a potential transfer to other future projects. A question in this survey asked the program managers about the timing of decisions to make use of the base platform designs in the new projects. In only 33% of the projects following sequential design transfer and design modification strategies had a decision about the usage of the particular base platform design been made before the base project was completed.

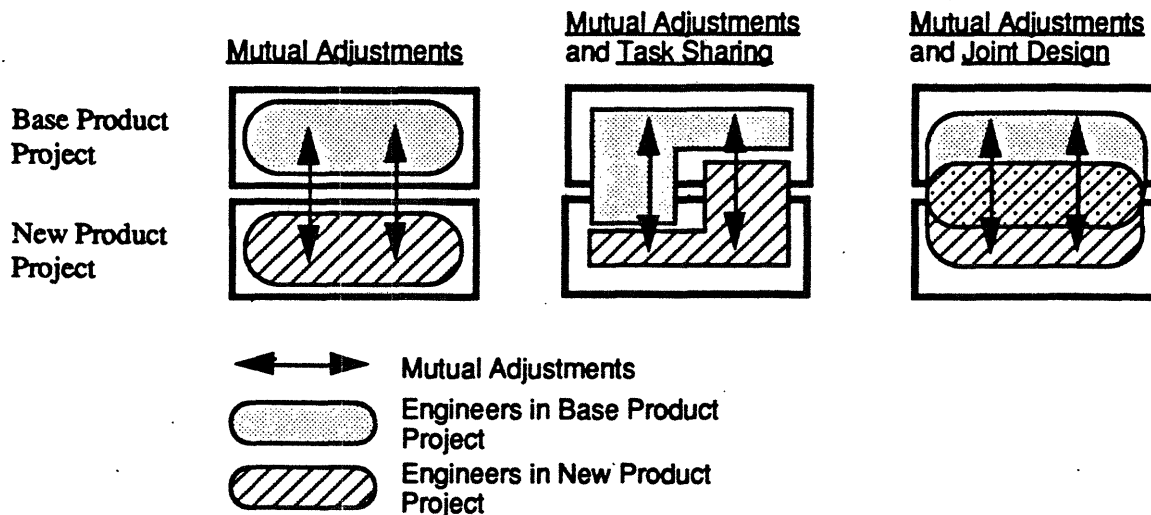
More importantly, even when there is an advanced plan during the base project which describes how a future project will modify and use the base project's platform design, there are often unexpected adjustments required during the new project. It is almost impossible to make accurate plans to modify the course of the base platform design to transfer it to the new project when there is such a long time lag between these two projects. It is difficult for engineers in the base project to predict problems a future project may have in using the old platform design. In particular, many potential problems with respect to the linking technologies become evident only after the new project starts, because these problems may become more obvious only after the design of other components begins. With respect to linking technologies, adjustments or changes in many cases cannot be completed within the platform engineering function.

(2) Mutual Adjustments, Task Sharing, and Joint Design

Whether or not there are such advanced plans, and partly because of interdependencies between component sub-systems, adjustment processes are so complicated that they can be more efficiently done through multiple iterations of feedback between the two projects. Because only rapid design transfer projects have significant overlap with a base project, only in rapid design

transfer projects can the engineers designing components implement mutual adjustments with base projects⁸.

Figure 5 Conceptual Models for Mutual Adjustments, Task Sharing, and Joint Design



In addition to the mutual adjustments, because of the overlapping and interactions, these two projects also can appropriately share engineering tasks and resources (task sharing). For example, in our interviews, some engineers explained that the same testing prototype can only be shared by multiple interrelated projects for data collection, when engineers in both projects cooperate closely. Moreover, in other cases, engineers from the two projects can jointly work on certain engineering tasks as a group (joint design). Mutual adjustments, task sharing and joint design with a base project, all of which can be appropriately implemented only in a rapid design transfer project, may have contributed to the reduction in engineering hours required. Conceptual models are shown in Figure 5.

(3) Transfer of "Fresh" Designs vs. "Dated" Designs

There are also fundamental problems with use of a "dated" platform design as a base in a new project following sequential design transfer or design modification. In our data, even in the projects using an existing or preceding design as a base, other components in the projects, including body and interior components, are mostly newly developed. This mixture may create some difficulties in linking the old platform design with new designs in other parts of the

⁸ By definition of our categorization scheme for the multi-project strategy types, explained earlier, only in rapid design transfer projects did engineers have overlap and actual interactions with engineers on other projects from which platform designs were transferred.

automobile. For example, over the past decade, the usage of CAD in design has become more extensive each year. The old designs might have been drawn on paper, instead of using a CAD tool, which has become common only in the last several years. One other example is the increasing use of plastic or aluminum materials for the body panels, which may not appropriately fit with older platform designs. Some engineers in our interviews also commented that design requirements evolving from customer needs, market competition, or governmental regulations often change after the original design is completed, especially when the time lag between the completion of the base design and its transfer to the new project is long. These difficulties may also increase the engineering hours of the sequential design transfer projects, because the modifications may become complicated.

(4) Problems of "Anonymous" Design

In sequential design transfer or design modification projects, design must often have been transferred from base projects through design drawings and specifications, because the base projects were already completed and the engineers for the base projects may have already started working on other projects. Some of these engineers may even have already left the firm. Therefore, it can be difficult for engineers on the new project to find and communicate with engineers who worked on the old base platform design. It may not be convenient for engineers who designed the base platform design to help the engineers on the new project understand the base design. Moreover, engineers for the completed base project may not have enough motivation to cooperate with the engineers for the new project, particularly when they have already started working on other projects that have nothing to do with the new project.

These issues are important because face-to-face design transfer is much more efficient than design transfer through specifications and drawings, particularly regarding some types of knowledge transfers. As our data suggest, an old base platform design always needs modification when it is used in other products. Some engineers in our interviews mentioned that, in order to modify a base design, they often need more knowledge than that which could be found in standard drawings or in CAD data. For example, the relationship between modifications in design and consequent changes in functionality is not shown in the drawings. Only engineers who actually worked on the base design may have that kind of information in their minds or notes. Second, knowledge about the base design that engineers in the new project may need to modify and adjust the base design to fit the new project may include intangible or tacit understanding. It is difficult for them to transfer that kind of design knowledge without actual overlap and interaction with engineers familiar with the base platform design (Nonaka, 1990; von Hippel, 1990).

(5) Role of a General Manager for Multi-Project Management

Finally, there is another organizational factor that may differentiate the productivity of rapid design transfer from other multi-project strategies. There are usually general managers or vice presidents above the project managers responsible for product development. These higher-level general managers are sometimes called platform managers, and have responsibility for multiple new product projects. They are likely to be responsible for both a base project and a rapid design transfer project, because the time lag between these projects is short. Because of the long time lag, it is less likely that the same general manager is responsible for both a base project and a sequential design transfer project, or for both a base project and a design modification project. This difference in leadership may affect the efficiency of design transfer between the two projects. For example, a general manager is likely to consider the total productivity of the base project and the rapid design transfer project together, while such concern is less likely if he or she expects to move on before a related follow-on project. In other words, the shorter the time lag between multiple interrelated projects, the greater the potential benefit of a single strong general manager, who would lead and manage multiple projects.⁹

As discussed in Section 3, some of the perspectives in the discussions above about the efficiency of rapid design transfer are analogous to the efficiency of managing overlaps among different functions. Multiple functions, at least to some extent, have a sequential nature in terms of tasking. Managing overlaps among multiple functions such as described by the term "simultaneous engineering" could lead to some negative implications due to the necessarily sequential nature of some tasks. On the other hand, by managing overlap among multiple projects, via "rapid design transfer", a firm may avoid these types of negative influences, as long as these projects coordinate with each other and mutually adjust their designs. We believe that this lack of negative implications also at least partially explains why our results demonstrated a strong gain in project productivity through rapid design transfer.

6-2 Communication between Project Managers

In order to implement the rapid design transfer strategy, there should be appropriate communication patterns among project managers for related projects. With respect to inter-project coordination between concurrent projects, engineers or functional managers in each design functioning in isolation, such as in a platform design department, may not be able to coordinate among multiple projects, even only with respect to the transfer of the platform design. An

⁹ A similar argument could be made not only for general managers, but also for other key functional engineering personnel who are responsible for component engineering on multiple projects.

automobile design is a system in which most major components are interdependent. Transfer of a certain component cannot be completed without considering its particular interdependencies with other components of each specific product project¹⁰. As Clark and Fujimoto (1991) discussed, cross-functional interactions caused by an interdependency are managed effectively only by project managers. Therefore, coordination between multiple project managers may be particularly important in the transfer of a platform design across multiple projects, in addition to coordination through functional managers who are responsible for specific components over multiple projects and coordination between engineers for different projects. In other words, even the component-level interactions between multiple projects may require project-level or system-level coordination when the components are parts of sub-systems and interdependent with other components within the project.

Therefore, in rapid design transfer projects, project managers may have had to communicate extensively with project managers in base projects. In order to examine this question, we asked the 103 project managers, in the same questionnaire survey, about the frequency of meetings on their project with project managers from other projects as well as with functional managers. Although we understood that the frequency of meetings may have varied during the course of the project, the questionnaire asked the project managers to estimate an average over the project's duration. The meetings are defined in the questionnaire to include both formal and informal ones. The results are shown in Table 3.

Table 3 Communication of Program Managers with Functional Managers and Program Managers for Other Projects

		Rapid Design Transfer Projects	Projects in Other Multi-Project Strategies
Frequency of Meetings (times/month)	Functional Managers	2.2	3.2
	Project Managers for other Projects	4.3	2.9
% of project managers who had meetings more frequently with other project managers than with functional managers**		48%	24%

** Difference significant at the 5% level

Project managers for rapid design transfer projects had meetings with other project managers more frequently (4.3 times a month) than managers for projects under other strategies (2.9 times). Project managers for rapid design transfer projects also met with functional managers

¹⁰ The perspective in which the majority of vehicle components form a sub-systems of a whole automobile design will be further discussed in the next section.

less frequently than project managers for other projects. As a result, almost half of the project managers (48%) for rapid design transfer projects had meetings with project managers of other projects more frequently than with functional managers. This number is significantly larger than the equivalent number for project managers of other multi-project strategy projects (24%). The data thus suggest that project managers for rapid design transfer projects seem to have needed to spend more time on inter-project coordination through meetings with project managers on the other project. In addition, the project manager's focus in their project management activities seems to shift at least some extent from cross-functional integration alone to both cross-functional integration and inter-project coordination at the project level.

6-3 Organizational Structure: Multi-Project Management

In order to manage concurrent multiple projects, a rapid design transfer project and its base project, there should be an appropriate organizational structure. In our interviews, we found that some manufacturers have been shifting their orientation from the management of a single project to multi-project management. Toyota's organizational evolution pattern shows an example of this trend. As Clark and Fujimoto (1991, pp. 276-280) discussed, by the late 1970s most Japanese companies had shifted from functionally-oriented organizations to project manager-based structures. By the mid 1980s, a few Japanese firms including Toyota had already shifted to relatively heavyweight project manager systems, or the "Shusa" system, which has been widely discussed (Ikari, 1985; Shiosawa, 1987). However, in 1993, Toyota created several chief engineers above shusas. Each of the chief engineers, by managing several shusas, is responsible for multiple concurrent projects. The person in this position assumes some of the authority that a powerful leader for a single project, a shusa, used to have. One of the primary purposes of creating a position more powerful than the shusa is facilitating the transfer and sharing of new designs among multiple projects. In doing so, Toyota's organization may have already shifted to a multi-project orientation.

In the past few years some other manufacturers in Japan, the U.S., and Europe have also introduced this type of organizational structure, so that multiple projects could also be managed by a strong control mechanism above project managers. One common mechanism for control is to divide the whole project portfolio into several groups and to place general managers above the individual project managers for individual projects. Although different manufacturers form their groupings differently, we were able to identify three categories from actual examples at nine manufacturers:

1. Design-oriented group (e.g., small vs. medium vs. large cars, front-wheel vs. rear-wheel drives.): Toyota, Ford, Chrysler, Fiat, Renault.
2. Plant-oriented group (e.g., products manufactured at plant A vs. plant B vs. plant C.): Honda.
3. Customer-oriented group (e.g., luxury vs. economical vs. sporty/leisure market segments.): Nissan, Mazda, Mitsubishi.

These differences may reflect each firm's priority for its multi-project strategy: either focusing on the efficiency of design, manufacturing or customer segment. The organizational processes in managing multiple projects may also be different. In order to explore these organizational issues, further studies including intensive interviews and internal document analyses are needed.

7 Conclusions

One of the key concepts that we proposed in this study with respect to multi-project management is rapid design transfer among multiple projects using overlapping coordination. This strategy provides firms with advantages in project productivity. Based on our interviews with engineers and project managers at U.S., Japanese, and European manufacturers, we also suggested several potential reasons for the efficiency of the rapid design transfer strategy. Only through rapid design transfer and multi-project coordination can a design be transferred from a base project to a new project with effective task sharing among engineers and mutual adjustments between the two projects. In addition, it may often be difficult to transfer a design from a relatively old project, as is the case with sequential design transfer. It is difficult to adjust an old design to a new architecture and the new requirements of the new product. Organizations at both the management level and the engineering level cannot strongly support a multi-project perspective when two or more projects are far apart from each other chronologically. In addition, we argued that in order to manage rapid design transfer, project managers for the new projects need to coordinate with project managers on the base projects from which the design is transferred. In our survey, project managers for rapid design transfer projects tended to have more meetings with project managers in other projects than project managers of projects following other strategies.

This paper also argued that organizational structures and processes that are appropriate for managing rapid design transfer may not be a traditional functional approach, because of the system characteristics of the products. Rather, they should be aimed at achieving both cross-functional coordination and intra-functional coordination simultaneously through the active coordination of multiple projects. This search for balance requires a multi-project management perspective, rather than a single-project management perspective. This approach would maximize the distinctiveness of product components essential to differentiate one product from another, but also reduces development time and costs as well as manufacturing expense by sharing as many components as possible. Companies may need either strong control above the matrix organization, or organizational structures and processes that enable system-level coordination across multiple projects. Because this study has primarily focused on strategic issues, further studies need to examine these organizational issues both theoretically and empirically.

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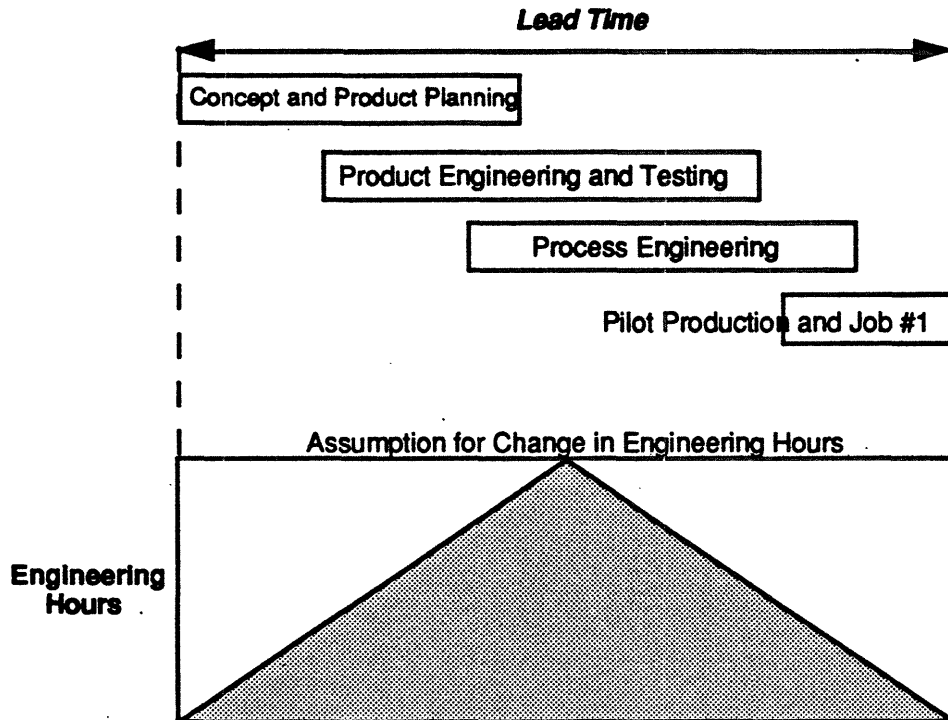
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Appendix 1 Definitions and Measurements of Lead Time and Engineering Hours

Lead Time

The questionnaire asked program managers to estimate the lead time from the beginning of concept and product planning to job #1. This period includes primary development tasks including "concept and product planning", "product engineering and testing", "process engineering", and "pilot production".



Descriptions of Each Stage of New Product Development

- **Concept Planning and Product Planning**

Product concepts such as target customers, selling points and major technical features are determined. In addition, through the synthesis of product engineering, product concepts, specific market needs, and cost constraints, the product's specification is determined. Performance targets are also determined.

- **Product Engineering and Testing**

Based on the product concepts, the performance target, and the major specifications, engineers design detailed engineering drawings. After a few pre-drawing releases to gain feedback from testing, the final drawings are released.

- **Process Engineering**

Based on the product information such as engineering drawings, the process design begins. The process design is transferred to tooling, NC tapes, and workers' manuals.

- **Pilot Production and Job #1**

In order to test the manufacturing process as it was designed, a product is produced in an actual production line. Then, actual production for sale, job 1, begins.

Appendix 1 (continued)

Engineering Hours

Engineering hours (EH) for each project are estimated as follows.

$$EH = (FS + PS * PR) * LT * WH / 2$$

FS: The number of engineers who worked on the project (full time).

PS: The number of engineers who worked on the project (part time).

PR: Average percentage of time part time engineers spent on one project*.

LT: Lead Time (months)

WH: Average monthly working hours per engineer*.

This estimation scheme is based on our interviews and discussions with engineers primarily at five Japanese firms. In this equation, the number is divided by two based on the assumption with respect to a typical pattern of changes in engineering hours throughout each project, as shown in the figure in the previous page.

Adjustments for Supplier Contribution

The data on average supplier contribution in component design for each manufacturer is obtained from the questionnaire survey of design engineers.

$$EHA = EH / (1 - SC)$$

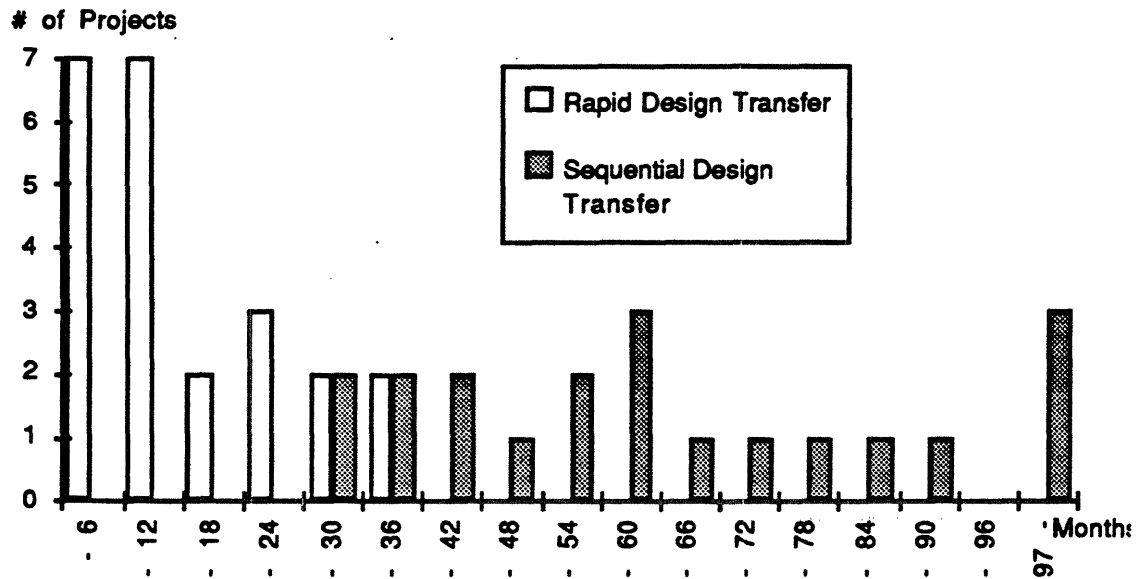
EHA: Adjusted engineering hours by supplier's contribution.

EH: Engineering hours explained above.

SC: Average supplier's contribution at the corporate level*.

(* The corporate-level average, obtained from the questionnaire survey of design engineers, which was conducted in the same research project. The method of this survey is described in Nobeoka, 1993)

Appendix 2 Difference in Time Lag with Base Project between Rapid Design Transfer and Sequential Design Transfer (N=103)



Appendix 3 Data on Project Content and Project Performance (N=76)

Platform Design	New Design	Rapid Design Transfer	Sequential Design Transfer	Design Modification	Total
# of Projects	18	18	16	24	76
Japanese	11	15	9	17	52
US	7	3	7	7	24
Price (\$)	21390 (8680)	16390 (7920)	15160 (7040)	16350 (7590)	17300 (8000)
# of Body Types	1.7 (0.6)	1.7 (0.5)	1.6 (0.8)	2.0 (0.9)	1.8 (0.7)
Truck/Van	4	4	2	4	14
New Design Ratio (%)					
Engine / Transmission	69 (34)	63 (39)	64 (37)	54 (36)	62 (37)
Body / Interior	98 (7)	89 (22)	94 (13)	83 (31)	90 (22)
Innovativeness Index (0-1)	0.33 (0.30)	0.33 (0.38)	0.22 (0.32)	0.08 (0.19)	0.23 (0.31)
Lead Time (months)	57.9 (14.0)	49.7 (11.1)	49.0 (13.3)	50.1 (15.2)	51.6 (13.8)
Engineering Hours (million hours)	1.89 (1.60)	0.72 (0.48)	2.02 (2.55)	1.95 (2.03)	1.66 (1.87)

Standard deviations are in parenthesis.