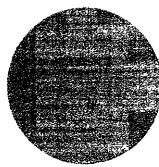


THE MIT JAPAN PROGRAM

日本 プログラム

Science, Technology,
Management

科学・技術・経営



**MULTI-PROJECT MANAGEMENT:
INTER-PROJECT INTERDEPENDENCY
AND ORGANIZATIONAL COORDINATION
IN NEW PRODUCT DEVELOPMENT**

Kentaro Nobeoka and Michael A. Cusumano
MITJP 94-13

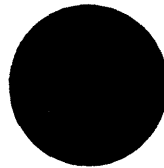
Center for International Studies
Massachusetts Institute of Technology

**Distributed Courtesy of the
MIT JAPAN PROGRAM
Science . Technology . Management**

**Rm. E38-7th Floor
Cambridge, MA 02139
Tel: (617) 253-2839
Fax: (617) 258-7432
E-mail: robart@mit.edu**

©MIT Japan Program

**Acknowledgements: The authors gratefully acknowledge the support
of the Sloan Foundation and the International Motor Vehicle Program (IMVP)
at the Massachusetts Institute of Technology.**



**MULTI-PROJECT MANAGEMENT:
INTER-PROJECT INTERDEPENDENCY
AND ORGANIZATIONAL COORDINATION
IN NEW PRODUCT DEVELOPMENT**

**Kentaro Nobeoka and Michael A. Cusumano
MITJP 94-13**

About the MIT Japan Program
and its Working Paper Series

The MIT Japan Program was founded in 1981 to create a new generation of technologically sophisticated "Japan-aware" scientists, engineers, and managers in the United States. The Program's corporate sponsors, as well as support from the government and from private foundations, have made it the largest, most comprehensive, and most widely emulated center of applied Japanese studies in the world.

The intellectual focus of the Program is to integrate the research methodologies of the social sciences, the humanities, and technology to approach issues confronting the United States and Japan in their relations involving science and technology. The Program is uniquely positioned to make use of MIT's extensive network of Japan-related resources, which include faculty, researchers, and library collections, as well as a Tokyo-based office. Through its three core activities, namely, education, research, and public awareness, the Program disseminates both to its sponsors and to the interested public its expertise on Japanese science and technology and on how that science and technology is managed.

The MIT Japan Program Working Paper Series provides an important means to achieving these ends.

Abstract

In many industries where product development is an expensive and time-consuming process, such when designing an automobile, the effective management of concurrent multiple projects that share components has become a critical issue. Firms need to coordinate engineers in different projects in order to leverage their design work and technical knowledge across more than one product. However, existing studies on product development have mostly focused on the management of one single project at a time, presumably operating in isolation. In contrast, this study explores the influence of inter-project interdependencies on organizational coordination requirements. A questionnaire survey of 256 component engineers in the U.S. and Japanese automobile firms provides evidence that the organizational coordination required to manage component design -- with and without inter-project interdependencies -- differs significantly. For example, in projects with no dependencies on other projects, only cross-functional coordination has a significant influence on schedule and cost performance. But in projects with dependencies on other projects, both intra-functional coordination and cross-functional coordination have a strong impact on performance in component design. We conclude that, in order to manage inter-project interdependencies effectively, firms need a new type of organization aimed at achieving both cross-functional coordination and intra-functional coordination simultaneously through the active coordination of multiple projects. This means that neither traditional project-oriented nor function-oriented organizations is appropriate for managing multiple projects that share components and thus have significant inter-project interdependencies.

1 Introduction

A stream of studies on new product development has been exploring differences in project performance based on the structure of engineering organizations and particular management or organizational processes. One of the central issues examined is the differences between project-oriented versus function-oriented organizations (Marquis and Straight, 1965; Galbraith, 1974; Davis and Lawrence, 1977; Allen, 1977; Tushman, 1978; Katz and Allen, 1985; Clark and Fujimoto, 1991). Most studies have argued that product development organizations require two different coordination mechanisms to achieve two major goals. First, in order to increase the quality and quantity of inputs of technical knowledge, companies need a high degree of coordination among technical specialties. Second, in order to integrate all technical knowledge toward well-defined products, companies need a high degree of coordination within and around a project.

Researchers have generally discussed these two aspects of coordination requirements with respect to the issue of how much balance is appropriate between a project versus a functional orientation in new product development organizations. However, one critical factor has been missing in this perspective. Nearly all existing studies have examined organizational coordination focusing primarily on the management of a single project. In many industries, however, such as automobile manufacturing, large companies have at least several product lines and simultaneously undertake multiple development projects. In these firms, the extent to which concurrent multiple projects can share key components or new technologies is an important strategic issue because of the direct relationship to economies of scale and scope in design, engineering, and manufacturing (Nobeoka and Cusumano, 1994). In addition, even when component designs are not exactly the same, firms may try to manufacture parts for a variety of projects using the same processing equipment.

This type of strategy selection usually causes interdependencies regarding specific technologies and components among multiple development projects. The nature of inter-project interdependencies should, in turn, have an influence on organizational coordination requirements. And these should be one of the key determinants in designing appropriate organizational structures and processes. This paper specifically explores the influence of inter-project interdependencies on organizational coordination requirements in new product development, focusing on the importance of both cross-functional (i.e., project) and intra-functional coordination.

There have been numerous studies on the advantages and disadvantages of project-oriented versus function-oriented organizations. In these empirical studies, project-oriented structures, rather than function-oriented structures, generally resulted in higher performance, particularly in terms of meeting cost and schedule targets. In some cases, functional orientation was more appropriate for maximizing technical performance of the product or component. For example, Marquis and Straight (1965), in their pioneering work, investigated 38 R&D projects under contract with a government agency and concluded that function-oriented organizations are more effective in technical performance, while project-oriented organizations tend to be more successful in cost and lead time. Katz and Allen (1985), who examined the relationship between project performance and the relative influence of project and functional managers, concluded that performance reaches its highest level when organizational influence is centered in the project manager and influence over technical details of the work is centered in the functional manager. Larson and Gobeli (1988), on the other hand, have found that in schedule, cost, and technical performance, project-oriented teams tend to be more successful than function-oriented organizations. In their study of automobile product development, Clark and Fujimoto (1991) also argued that strong project manager responsibility (i.e., the "heavyweight project manager") had a positive influence on project lead time, productivity, and design quality.

These studies have provided useful insights for managing new product development projects. But few studies have explicitly addressed questions of inter-project interdependencies in design or engineering, either conceptually or empirically. It is important to study the influence of inter-project interdependency on organizational coordination requirements because these should impose a critical dimension of contingency on product development organizations. The findings and frameworks of the existing studies that do not consider this dimension may have been misleading and may have to be reinterpreted.

For example, the existing literature suggests that, in order to shorten lead time, a project-oriented organization is the most appropriate structure (Clark and Fujimoto, 1991). Yet one of the critical issues many automobile manufacturers currently face is how to reduce costs by sharing components and technical knowledge among multiple projects. A project organization that is too project-oriented or too autonomous may result in the development of too many components unique to each project, and thus may require excessive financial and engineering resources. The next question is whether firms should adopt a traditional function-oriented organization when management of inter-project interdependencies is critical. This might involve component departments (such as for brake or engine design) providing mostly standard parts, which projects or design departments would incorporate in new products. If there are inter-project interdependencies, however, such as how to design one braking system or engine to fit two or more new vehicles, they cannot be managed within each functional department acting in isolation. Furthermore, the inter-project management process should still take into consideration the needs of an individual project to make sure that a good product results.

This study is unique in that it focuses on issues related to the management of multiple interdependent projects. In the next section, we discuss the potential influence of inter-project interdependencies on organizational requirements, particularly with respect to cross-functional and intra-functional coordination in new product development organizations. Cross-functional

coordination is directly related to coordination around a project, and intra-functional coordination within each function. The following sections explain our research methods and the results from a questionnaire survey of 256 design engineers in ten international automobile firms. These sections provide evidence that the organizational coordination required to manage component design differs significantly depending on whether or not inter-project interdependencies exist. In the final section, we discuss theoretical and managerial implications drawn from our survey results.

2 Framework and Hypotheses

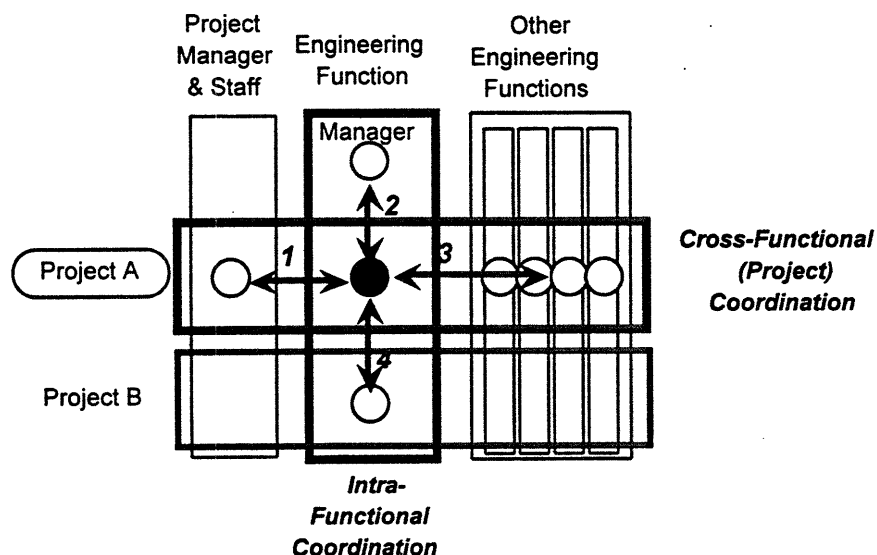
New product development organizations in most large automobile firms appear to be matrix structures, although there are some variations with respect to the degree of authority granted to projects as opposed to functional departments (Clark and Fujimoto, 1991). In order to examine the influence of inter-project interdependencies on organizational coordination, our study used two separate simplified patterns of component design engineering as a research framework. In the first pattern, an engineer designs components for a new vehicle project that has no direct interdependency with any other on-going product development project. In the second pattern, an engineer designs components for a new vehicle project that has some direct interdependency with equivalent components in at least one other on-going project.

The inter-project interdependencies can exist when two projects share at least some portion of component designs or divide some tasks to avoid duplications in engineering. Utilizing the same manufacturing equipment may also cause some interdependencies between different vehicle projects. Figures 1 and 2 illustrate the differences in a simplified model of a matrix product development organization, positioning design engineers in an engineering function at the center of the matrix.

2-1 Hypotheses on Component Design without Inter-Project Interdependency

Figure 1 shows the first pattern. An engineer designs a component for Project A that does not have any particular interdependencies with Project B. Each design engineer works both for a functional manager, primarily on issues pertaining to technical or component questions (indicated by the number 2 in Figure 1), and for a project manager, primarily on issues pertaining to the integration of information inputs and intermediate outputs in order to design a specific final product (1 in Figure 1). In addition, many engineers formally or informally interact with engineers in other functions such as manufacturing and different component groups, who work for the same new product project, to integrate technical outputs across functional areas (3 in Figure 1). Furthermore, even in this model, engineers may want to have some interactions and coordination with engineers in the same technical discipline, including those who work for other projects, to update and refine "state-of-the-art" technologies (4 in Figure 1).

Figure 1 Cross-Functional Coordination and Intra-Functional Coordination



In the framework shown in this figure, cross-functional coordination is defined as the degree of coordination between the design engineers and a project manager (including his or her staff) as well as engineers in other engineering functions. "Other engineering functions" consist of design engineers for other components and manufacturing engineers who work for Project A. Intra-functional coordination refers to the degree of coordination between engineers and a functional manager as well as engineers in their same technical function or system area who work for other vehicle projects. The same definition of coordination is also applied to the next model shown in Figure 2.

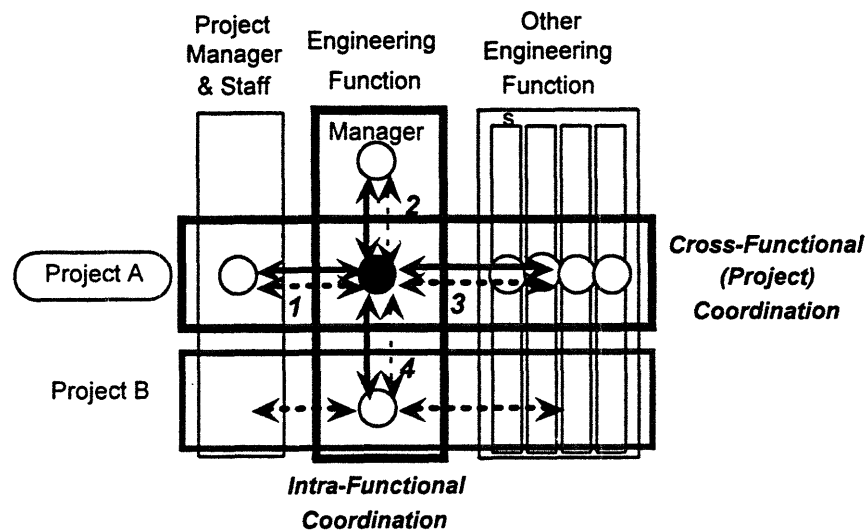
Based on past studies cited above, we hypothesize that, *without* inter-project interdependencies with respect to certain components, cross-functional coordination may have a particularly strong positive influence on operational performance such as meeting cost and schedule targets. In addition, intra-functional coordination may be more important than cross-functional coordination, particularly regarding technical performance.

2-2 Hypotheses on Component Design with Inter-Project Interdependency

The model in Figure 2 shows the next hypotheses regarding possible influences of inter-project interdependency on the degree of organizational coordination. The potential additional organizational requirements for coordination are indicated by the dotted lines. This model assumes that there is an interdependency between two projects regarding at least the design of a particular component, on which the engineer in the center of the figure works. In the model outlined in Figure 2, the engineer working for Project A develops a design in conjunction with Project B, in which the engineer is not directly involved. We chose this research framework, as opposed to an alternative model in which the same engineers work on component designs for multiple product projects, because our research aim here is to explore the requirements for

organizational coordination when multiple projects are interdependent at the same time that the engineers work in separate projects.

Figure 2 Influence of Inter-project Interdependencies



Assume that requirements for the component's design are not the same between these two projects, and that these two vehicle projects target different customer groups and compete against different competitors. In other words, engineers for Project A and B may not use exactly the same design, but they try to share some resources or technologies (such as the same core braking or engine systems, but with some modifications for different products). In this case, additional coordination between engineers involved in these two different projects may be needed in order to minimize task duplications or to share as much of the design as possible (indicated by 4 in Figure 2). This coordination effort may also have to be overseen by the functional manager (2 in Figure 2). The degree of intra-functional coordination, therefore, may have a stronger influence on project performance in this kind of design work than in a project without any inter-project

interdependencies. In other words, more coordination may be needed within the functional group because of the interdependency.

More importantly, in addition to this relatively direct requirement of the intra-functional coordination between engineers on the two projects, requirements for cross-functional coordination may be higher than in projects without inter-project interdependencies (*1* and *3* in Figure 2). A product development project is a system consisting of multiple closely coupled engineering functions (Rosenberg, 1982; Iansiti, 1993). Uncertainty in any part of the vehicle system increases the requirement for coordination across sub-systems (Tushman, 1979; Clark and Fujimoto, 1991). In other words, uncertainty in the design of each component within a functional sub-system increases the coordination requirements across the entire system of a new product project. Uncertainty in the engineer's task within a function, in this model, is higher than that in a project without any interdependencies with other vehicle projects.

For example, suppose that engineers for Project A have to modify design specifications of a certain component in order to share some portion of the design with an equivalent component for Project B. In this case, a design change in Project A is caused by its interdependency with Project B. The change must be also incorporated into the whole vehicle system done within Project A. Therefore, the design change should require additional cross-functional coordination within Project A, in addition to coordination between engineers in Project A and B within the same function (such as the engine design department). Thus, we hypothesize that, in a component design that is interdependent with another project, the influence of cross-functional coordination on design performance is stronger than in projects without inter-project interdependencies. In addition, the more interdependent components are with other components within a project (for example, the platform, engine, braking, and transmission systems all need to be closely coordinated), the more difficult it may be to coordinate component design between multiple projects that want to share one or more components.

We sum up the hypotheses for additional coordination requirements for component design with interdependencies as follows: the importance of both cross-functional cooperation and intra-functional cooperation for design performance may be significantly higher in projects with inter-project interdependencies and interactions than in those without this type of inter-project interactions.

3 Sample and Measures

To examine these hypotheses, we conducted a questionnaire survey of design engineers at seven Japanese and three U.S. auto manufacturers. The questionnaires were distributed in April 1992 and collected between May and August in the same year. One central contact at each company distributed the questionnaires to design engineers. We asked the contact persons to distribute the questionnaires to engineers in as many different engineering divisions as possible, such as chassis, body, and engine. In addition, we requested that the questionnaires be filled out by junior engineers who actually designed components rather than senior engineers or managers. Of 280 questionnaires sent to Japanese firms and 90 questionnaires sent to U.S. firms, 224 (80%) and 32 (36%) were returned, respectively, which resulted in a total sample of 256 responses¹. The low return rate from the U.S. firms may have resulted from the U.S. firms' reluctance to provide data on poorly-implemented projects, a reticence which we noticed in discussions with them. Because the primary 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 we also used control variables to detect possible differences between the two samples.

¹ These percentages are not return rates as the term is commonly used. The actual number of questionnaires distributed to engineers and the selection of engineers were decided primarily by the contact persons. The only guideline with respect to the number of questionnaires was to distribute the questionnaires to at most 35 engineers in as many different design functions as possible within each firm.

In the questionnaire, respondents chose one specific component that they recently had worked on for a specific product development project, excluding components built for basic research or for general use. One of the questions asked whether, in conjunction with the vehicle project for which the respondent worked, there was at least one other new vehicle development project that was using similar component designs and was sharing some of the technology or designs of the respondent's project, which necessitated some inter-project interactions. Respondents were asked to think only about other projects in which they were not directly involved, so that the issue of coordination could be explicitly explored. Among 256 component developments, 122 appeared to have at least one other project with which they had this type of inter-project interdependency. Thirteen of the 32 U.S. component developments (41%) and 109 out of 224 Japanese component developments (49%) exhibited inter-project interdependencies. We analyzed data separating these two sample groups (i.e., with and without interdependencies to other projects) to explore how organizational requirements differed between these two types of component development.

3-1 Performance Measurements

The questionnaire asked respondents to rate on a 7-point Likert-type scale whether each component development performed above or below their expectations in schedule, cost, design quality, and degree of meeting customer needs. We averaged cost and schedule performance data to measure operational performance, because these variables are highly correlated and seem to capture a common factor both conceptually and statistically (% explained by the first principal component = 83%). For the same reason, we averaged performance ratings of design quality and the degree of meeting customer needs to measure design quality performance (% explained by the first principal component = 87%).

3-2 Measurements of the Degree of Coordination

There is no single best measurement of the degree of coordination. The degree of coordination among different groups rather than the specific means of coordination needs to be stressed in this particular analysis. The degree of communication has been used to measure coordination (Allen, 1977; Tushman, 1978), although this is not a good measure of coordination when extensive communication is needed to solve problems or conflicts. The degree of goal sharing among different groups could be an alternative measure, as used by Lawrence and Lorsch (1967). This is not a good measurement for this study either, however, because all groups which responded to the survey are in a specific new product development project, and there may not be enough natural variations in their goals. Thus, in this study, as a proxy for the degree of coordination between different groups, we decided to measure the degree of satisfaction with the cooperative working relationship on the particular engineering task that each respondent chose. This variable captures the willingness or ability of engineers and managers in one group to cooperate with their counterparts in other groups. Respondents rated the satisfaction level of their working relationship regarding a specific component development with people in different groups: a functional manager, a project manager, product engineers in other functions, manufacturing engineers, as well as engineers in their same technical function working for other projects.

First, we averaged ratings regarding product engineers in other functions and manufacturing engineers to measure the degree of coordination (i.e., satisfaction with the working relationships on particular engineering tasks) with engineers in other functions. Second, as indicated in the model shown in Figures 1 and 2, we calculated the degrees of cross-functional coordination and intra-functional coordination. We averaged the degrees of coordination with a project manager and with engineers in other functions to measure the degree of cross-functional

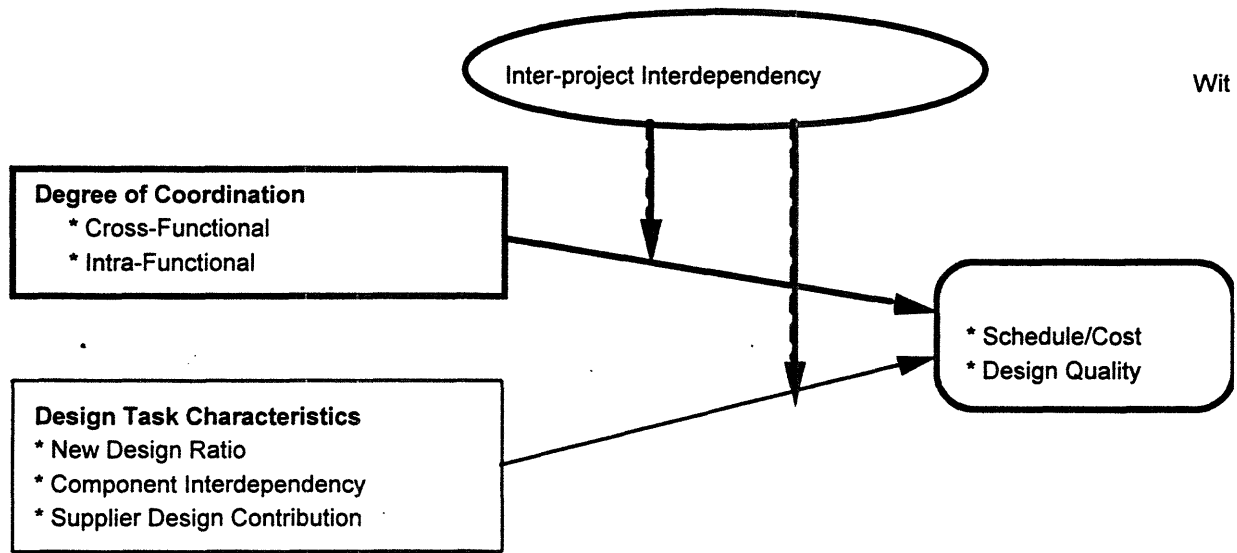
coordination. We averaged the degrees of coordination with a functional manager and with other engineers in the same function to obtain the measure of intra-functional coordination.

3-3 Control Variables and Analytical Framework

The analytical framework in Figure 3 summarizes other variables of component design task characteristics that may affect the relationship between component development performance and any type of organizational coordination. We added these control variables because they may identify additional task complexity, which might make component design more difficult and lead to lower performance ratings regardless of the degree of coordination. These variables might also have different influences on design performance depending upon whether there are inter-project interdependencies.

First, we asked respondents to estimate the percentage of new design as opposed to the carried-over portion of the design for each new component development. Many “new” designs are not 100% new, because engineers often use or carry over existing designs as a base. This ratio should be controlled because components with more new design may require more inputs from other engineers within the same function, including engineers working for other projects. On average, 79% of the designs in the component developments with inter-project interdependencies were newly designed, and 86% of the designs were new in projects without inter-project interdependencies. Second, respondents estimated a component's inter-functional interdependency with other parts of the product by rating, on a 7-point Likert-type scale, the extent the component design affects other parts of the product. Third, respondents estimated the percentage of design that suppliers did for each component. On average, suppliers did 34% of the design for components with inter-project interdependencies and 31% in those without interdependencies.

Figure 3 Analytical Framework of the Relationship between Coordination and Performance



4 Results

Table 1 shows descriptive data and a correlation matrix for component development with inter-project interdependencies (top half) and without (bottom half). On average, engineers who work on component design without inter-project interdependencies rated the component's performance higher than those who worked on component design with interdependencies. The degree of organizational coordination is also rated higher in component design without inter-project interdependencies, which suggests that achieving high levels of coordination is generally more difficult in component design with inter-project interdependencies. The current research, however, focuses on the differences between these two types of component design in the

relationship between project performance and the different types of coordination, rather than the differences in performance or the degree of coordination alone.

Table 1 Descriptive Data and Correlation Matrix

With Inter-project Interdependencies (N=122)

	Mean	S.D.	1	2	3	4	5	6	7
1 Performance: Schedule/Cost	3.47	.86							
2 Performance: Design Quality	4.37	.96	.36 ***						
3 Coordination: Cross-Functional	4.36	1.00	.39 ***	.38 ***					
4 Coordination: Intra-Functional	4.50	1.10	.37 ***	.34 ***	.59 ***				
5 Component Interdependency	4.82	1.73	-.06	.24 ***	.35 ***	.13			
6 New Design Ratio	.79	.29	.02	.02	.06	.03	.13		
7 Supplier's Design Contribution	.34	.25	-.11	-.12	.02	.13	-.04	-.03	

Without Inter-project Interdependencies (N=134)

	Mean	S.D.	1	2	3	4	5	6	7
1 Performance: Schedule/Cost	3.69	1.05							
2 Performance: Design Quality	4.66	.99	.37 ***						
3 Coordination: Cross-Functional	4.66	1.00	.25 ***	.19 **					
4 Coordination: Intra-Functional	4.69	1.09	.15	.26 ***	.55 ***				
5 Component Interdependency	4.90	1.57	-.04	.02	.03	.01			
6 New Design Ratio	.86	.24	.14	.12	.11	.05	.30 ***		
7 Supplier's Design Contribution	.31	.23	-.06	-.13	-.05	-.12	-.16	-.12	

p<.05; *p<.01

Performance variables, in general, are correlated more strongly with the coordination variables in component developments with inter-project interdependencies than those without the interdependencies. Specifically, in component development with inter-project interdependencies, both measurements of performance, those for schedule/cost and design quality, are strongly correlated with both cross-functional and intra-functional coordination variables. On the other hand, in cases without inter-project interdependencies, schedule/cost performance is significantly correlated only with cross-functional coordination, while design quality is strongly correlated only with intra-functional coordination. The results from the simple correlation matrix show that

component design with inter-project interdependencies requires both cross-functional and intra-functional coordination to be successful. Component design without the interdependencies particularly requires cross-functional coordination for schedule and cost control, and intra-functional coordination for design quality. These results with respect to component design without inter-project interdependencies fit with past studies (for example, Marquis and Straight, 1965; Katz and Allen, 1985). The following analyses explore these relationships more precisely, using regression analyses that add control variables.

4-1 Schedule/Cost Performance

Table 2 shows the regression results for project performance in terms of schedules and costs. The results show that the organizational coordination required to perform well differs significantly between component design with and without inter-project interdependency. The differences generally support our hypotheses.

First, in component design without inter-project interdependencies, as most past studies have found, cross-functional coordination, not intra-functional coordination, is particularly important to meeting schedule and cost targets. Second, in component design with inter-project interdependencies, intra-functional coordination is important to manage inter-project coordination even for schedule/cost performance. Third, the influence of cross-functional coordination is stronger in component design with inter-project interdependencies than in design without interdependencies. These results support the view that, in order to manage inter-project interdependencies, not only is strong intra-project coordination required to deal with inter-project interdependency, but also cross-functional coordination is required to absorb within each project any uncertainties caused by inter-project interdependencies.

Table 2 Regression Analysis for Performance in Schedule and Cost

Independent variables	With Interdependencies (N=122)		Without Interdependencies (N=134)	
	Model1	Model 2	Model 3	Model 4
Constant	0.00	0.00	0.00	0.00
Degree of Coordination				
Cross-Functional		0.34 ***		0.19 *
Intra-Functional		0.20 *		0.01
Component Interdependency	-0.10	-0.23 ***	-0.13	-0.12
Supplier's Design Contribution	-0.14	-0.17 *	-0.06	-0.05
New Design Ratio	0.06	0.04	0.16 *	0.14
Nation (US=1, Japan=0)	0.19 **	0.12	0.23 ***	0.19 **
Adjusted Squared Multiple R	0.02	0.22	0.06	0.08

Coefficients are standardized numbers. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In addition to the differences in the influence of organizational coordination variables, other design task variables also affect performance differently between these two types of component design. First, as our hypothesis suggests, a component's interdependency with other parts of the vehicle causes more difficulties in component design when there are inter-project interdependencies. When the cross-functional component interdependency is strong, inter-project interdependency cannot be managed within each function. Second, the extent of supplier contribution has a significant negative effect on performance only in component design with inter-project interdependencies. This result may imply that it is difficult for multiple projects to manage a supplier relationship jointly.

These independent variables, especially the organizational coordination variables, explain more about schedule and cost performance in component design with inter-project interdependencies (adjusted $R^2=0.22$) than in design situations without interdependencies (adjusted $R^2=0.08$). This difference may imply that coordination variables are particularly

important in component design with interdependencies, because of the more complicated coordination tasks.

4-2 Design Quality Performance

Design quality performance is also significantly affected by both cross-functional coordination and intra-functional coordination only in component design with inter-project interdependencies, as shown in Table 3. In design without interdependencies, intra-functional coordination is particularly important, which again generally fits with the results from past studies discussed earlier. In addition, a supplier's contribution to the design again has a stronger negative influence on design quality performance in component design with inter-project interdependencies.

Table 3 Regression Analysis for Performance in Design Quality

Independent variables	With Interdependencies (N=122)		Without Interdependencies (N=134)	
	Model1	Model 2	Model 3	Model 4
Constant	0.00	0.00	0.00	0.00
Degree of Coordination				
Cross-Functional		0.20 *		-0.02
Intra-Functional		0.17 *		0.20 **
Component Interdependency	0.17 **	0.09	-0.09	-0.08
Supplier's Design Contribution	-0.16 *	-0.18 **	-0.13	-0.10
New Design Ratio	0.05	0.03	0.11	0.11
Nation (US=1, Japan=0)	0.35 ***	0.30 ***	0.41 ***	0.38 ***
Adjusted Squared Multiple R	0.16	0.25	0.17	0.19

Coefficients are standardized numbers. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

As Tables 2 and 3 both indicate, respondents at the U.S. firms tended to rate their performance higher than the Japanese respondents. This may have been caused by more selectivity and the low return rate from the U.S. firms, who indicated that they preferred to return

surveys only for high-performing component design projects, as pointed out earlier. This difference may also reflect the difference in language, either in English or Japanese, used in the questionnaire. In any case, this bias does not affect the results regarding the general theoretical propositions posed.

4-3 Summary

Table 4 summarizes the influence of coordination and task variables on design performance. It is evident that organizational requirements significantly differ between component design with and without inter-project interdependencies.

Table 4 Summary of the Regression Analyses

		Cross-Functional Coordination	Intra-Functional Coordination	Component Inter-dependency	Supplier's Design Involvement
<i>With Interdependencies</i>	Schedule/Cost	***	*	*** (Negative)	* (Negative)
	Design Quality	*	*		** (Negative)
<i>Without Interdependencies</i>	Schedule/Cost	*			
	Design Quality		**		

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

In component design development in the context of inter-project interdependencies, organizational coordination in general tends to have a stronger impact on performance than in designs without those interdependencies. Specifically, the influences of both cross-functional

coordination and intra-functional coordination are strong in designs with inter-project interdependencies. Intra-functional coordination, which directly involves engineers across multiple projects, affects schedule/cost performance only in those designs with inter-project interdependencies. In addition, design quality is affected by cross-functional coordination only in component design with inter-project interdependencies. With respect to coordination requirements for component design without inter-project interdependencies, our data basically fit the findings from past studies. In a component design without inter-project interdependency, cross-functional coordination is particularly important for operational performance such as meeting schedule and cost targets. Design quality is more greatly influenced by intra-functional coordination among engineers in the same technical discipline than cross-functional coordination.

Complexity caused by other task characteristics, such as component interdependency with other parts of the product and the degree of supplier involvement in design, seems to impose greater penalties on component design with inter-project interdependencies. This may be because component design without inter-project interdependencies is simpler than design with interdependencies, and thus it may be easier to manage the complexity of component interdependency and a supplier's involvement. In addition, this result supports the hypothesis that interdependency with other components makes it difficult to manage inter-project interdependencies. Otherwise, a traditional functional organization could manage inter-project interdependencies within each function.

5 Discussion and Conclusions

The results of this survey indicate that, in order to effectively manage schedules, costs, and design quality for component design across multiple interrelated projects, firms need not

only stronger intra-functional coordination but also stronger cross-functional coordination than in single-project component design. In addition, other factors that impose further complexity on the organization, such as high levels of component interdependency and supplier involvement, tend to cause greater difficulties to the organization engaged in component design with inter-project interdependencies. This result implies that different theoretical models are required to predict the relationship between organizational coordination patterns and project performance, depending on the nature of inter-project interdependencies. In our sample, about half of the engineers designed components that had some direct interdependencies with other vehicle projects. A simplified theory based on the context of a single project cannot directly apply to this type of multi-project management.

This study also suggests several implications for managers. The coordination requirements for component design with inter-project interdependencies are so different from those without interdependencies that different organizational structures and processes are likely to be needed. For example, our data supports other research which argues that, in order to shorten lead time in a single-project context, firms should adopt a project-oriented organization. However, our study suggests that this solution is appropriate only when inter-project interdependency is not an issue. At the same time, even when an interdependency exists, this study suggests that organizational structures and processes should not depart completely from a project-oriented management system. Rather, organizations should simultaneously aim at achieving both cross-functional coordination (which projects do well) and intra-functional coordination (which functional departments do well) through the active coordination and management of multiple projects. This goal cannot be achieved by either traditional project-oriented or function-oriented organizations. The inter-project interdependencies must be coordinated within the context of a specific project as a system. In other words, firms need

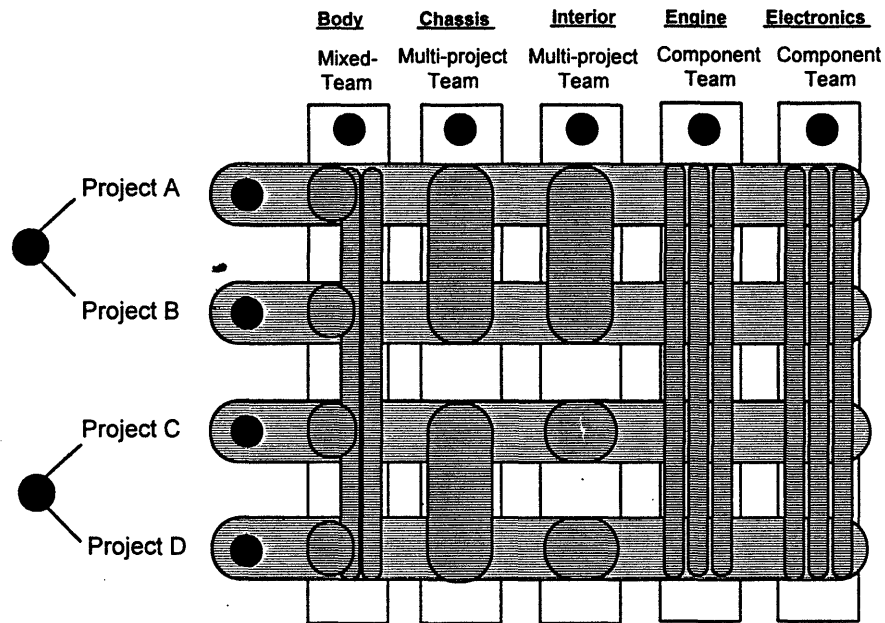
organizational structures and processes that enable system-level coordination for each project and for multiple projects.

As product development competition intensifies in many industries, firms may have to place more importance on the management of concurrent multiple projects. In our follow-up interviews², we found that some firms have actually introduced some new concepts into their organizations to deal with inter-project interdependencies. First, some Japanese automobile firms have employed the idea of extensively differentiated mechanisms within a matrix organization. They are creating a variety of working structures to manage different design tasks based on an explicit recognition of the degree of inter-project and cross-functional interdependencies. Figure 4 depicts an example of a *differentiated matrix* from one of the Japanese automobile firms. Depending on the nature of the interdependency, there is flexibility in changing task partitioning and organizational structure.

For example, easily standardized components like batteries and audio systems in the electronics design division tend to be developed by a dedicated component group, while platform components are developed by a multi-project team. Engineers working on some body components are totally devoted to a single project through a project-oriented group in order to make sure that each product has a distinctive feel and appearance to the customer. Because the nature of both cross-functional and inter-project interdependencies changes continuously depending on the combination of projects being developed and their strategies, a company should be able to quickly and dynamically change this micro-level structure.

² Our field study included three trips to Japan, one to Europe, and several to Detroit, augmented by numerous interviews around Boston with International Motor Vehicle Program participants. 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 August 1992 and July 1994.

Figure 4 An Example of Differentiated Matrix Organization



Second, some firms introduced a level of strong control above project managers and now have "group" project managers who are responsible for multiple concurrent projects, so that coordination among multiple projects can be more effectively achieved. One common mechanism for control is to divide the whole project portfolio into several groups (such as by platform size, customer group, or manufacturing plants) and to place general managers above the individual project managers for individual projects. A good example can be seen in Toyota's major reorganization in 1992 around different platforms. By the late 1970s, Toyota had already shifted from a functionally-oriented organization to a project-based structure. Its *shusa* or heavyweight project-manager system has been widely discussed as an example of an effective project-oriented organization (Ikari, 1985; Shiosawa, 1987; Clark and Fujimoto, 1991). However, Toyota now has a chief engineer above individual project *shusas* who is responsible for several concurrent projects. The person in this position assumes some authority that a

powerful leader for a single project, a shusa, used to have (such as the budget authority to develop a new engine or a new platform for one particular vehicle). One of Toyota's main purposes for creating a position more powerful than the shusa was to facilitate the transfer and sharing of new designs among multiple projects.

This shift at Toyota is but one example from the automobile industry. Honda and Mitsubishi in Japan, General Motors in the United States, and Fiat and Volkswagen in Europe all have reorganized in recent years to manage inter-project interdependencies more effectively. There are also examples from other industries, including consumer electronics (Sanderson and Uzumeri, 1990), computer hardware (Iansiti, 1994; Baldwin and Clark, 1994), and computer software (Cusumano and Selby, 1995), where companies as prominent as Sony, NEC, Sun Microsystems, and Microsoft have reorganized or redesigned their products in order to share components more effectively across related products. But while inter-project interdependency is probably a broad-based phenomenon and an increasingly common managerial problem for firms that want to introduce many new products while restraining engineering costs, most product-development research continues to focus -- unrealistically, in many cases -- on the management of individual projects in isolation. As part of an ongoing research program, we are exploring further this concept of a "dynamic" differentiated matrix structure as well as conducting additional surveys and writing detailed case studies at leading automobile companies in the United States, Japan, and Europe in order to understand better the evolution of product development organizations and practices that facilitate the sharing of design knowledge and specific components across multiple projects.

References

- Allen, Thomas J.: 1977. Managing the Flow of Technology, Cambridge, Mass, MIT Press.
- Baldwin, Carliss Y., and Kim B. Clark: 1994. "Sun Wars: Competition within a Modular Cluster." Boston, MA, The Colliding Worlds Colloquium, Harvard Business School.
- Clark, Kim B., and Takahiro Fujimoto: 1991. Product Development Performance: Strategy, Organization, and Management in the World Auto Industry, Boston, MA, Harvard Business School Press.
- Cusumano, Michael A., and Richard W. Selby: 1995. Microsoft Secrets, New York, Free Press (forthcoming).
- Davis, Stanley M. and Paul R. Lawrence: 1977. Matrix, Massachusetts, Addison-Wesley..
- Galbraith, J. R.: 1974. "Organization Design: An Information Processing View", *Interfaces*, 4, May, 28-36.
- Ikari, Yoshiro: 1985. Toyota tai Nissan: Shinsha Kaihatsu no Saizensen (Toyota versus Nissan: The Front Line of New Car Development). Tokyo, Diamond.
- Imai, K., I. Nonaka and H. Takeuchi: 1985. "Managing the New Product Development Process: How Japanese Learn and Unlearn," in K. B. Clark et al., ed., The Uneasy Alliance: Managing the Productivity-Technology Dilemma (Boston, MA, Harvard Business School Press).
- Iansiti, Marco: 1993. "Technology Integration: Managing Technological Evolution in a Complex Environment." Working paper #93-057, HBS.
- Iansiti, Marco: 1994. "Shooting the Rapids: System Focused Product Development in the Computer and Multimedia Environment." Boston, MA, The Colliding Worlds Colloquium, Harvard Business School.
- Katz, Ralph and Thomas J. Allen: 1985. "Project Performance and the Locus of Influence in the R&D Matrix", *Academy of Management Journal*, 28, 1,67-87.
- Larson, Erik W. and David H. Gobeli: 1988. "Organizing for Product Development Projects", *Journal of Product Innovation Management*, 5,180-190.

- Lawrence, Paul R. and Jay W. Lorsch: 1967. Organization and Environments: Managing Differentiation and Integration, Homewood, IL, Irwin.
- Marquis, Donald G. and D. L. Straight: 1965. "Organizational Factors in Project Performance", Unpublished Working Paper, MIT Sloan School of Management.
- Nobeoka, Kentaro and Michael A. Cusumano: 1994. "Multi-Project Strategy and Market-Share Growth: The Benefits of Rapid Design Transfer in New Product Development", Unpublished Working Paper, MIT Sloan School of Management, WP #3686-94/BPS.
- Rosenberg, Nathan: 1982. Inside the Black Box: Technology and Economics, Cambridge, MA, Cambridge University Press.
- Sanderson, Susan W., and Vic Uzumeri: 1990. "Strategies for New Product Development and Renewal: Design-Based Incrementalism." Troy, N.Y., Rensselaer Polytechnic Institute, Center for Science and Technology Policy, Working Paper.
- Shiosawa, Shigeru: 1987. The Chief Engineer: Project Teams of Toyota, Tokyo, Japan, Kodansha.
- Tushman, Michael L.: 1978. "Technical Communication in R&D Laboratories: The Impact of Project Work Characteristics", *Academy of Management Journal*, Vol. 21, No. 4, 624-645.