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MULTIPROJECT STRATEGY AND SALES GROWTH: THE BENEFITS OF RAPID DESIGN TRANSFER IN NEW PRODUCT DEVELOPMENT

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This paper explores the impact on sales growth of different product development strategies, especially an approach that focuses on the coordination of multiple projects that overlap in time and share critical components. The data for our analysis comes from the automobile industry, although the principles we discuss should apply to any industry where firms compete with multiple product lines and where the sharing of components among more than one distinct product is both possible and desirable. Some firms compete by trying to develop 'hit' products in isolation, with little or no reuse of components or coordination with other products. Another way to compete is to leverage a firm's investment in new technologies across as many new products as possible as quickly as possible, while the technologies are still relatively new. This paper proposes a typology that captures this effect by categorizing product development strategies into four types: new design, rapid (or concurrent) design transfer, sequential design transfer, and design modification. *An analysis of 210 projects from the automobile industry between 1980 and 1991 indicates that firms utilizing the rapid design transfer strategy—quickly leveraging new platform components across multiple projects–increased sales more than when they or their competitors did not use this strategy. The study's results suggest that not only the* sharing of technology among multiple projects *but also the* speed of technology leveraging *are important to sales growth.* © 1997 by John Wiley & Sons, Ltd.

INTRODUCTION

Various authors suggest that the competitive environment in many industries has been changing in recent years as product life cycles have shortened and as customers have demanded increasing levels of product variety (Stalk and Hout, 1990; Wheelwright and Clark, 1992; Sanchez, 1995). Many companies have also been trying to introduce new products and product variations at prices comparable to traditional low-cost mass-produced goods (Cusumano, 1992; Pine, 1993; Kotha, 1995). As a result, companies that once competed successfully by developing 'hit' products in isolation, without trying to minimize development time or engineering costs by, for example, reusing key components or sharing critical technologies from other projects in the company, may now find themselves unable to compete effectively with firms that have deliberate strategies and processes for sharing technologies across a portfolio of projects (Ellison *et al.*, 1995). In this paper, we refer to these policies and capabilities for internal technology transfer

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in new product development as 'multiproject' strategy and management. The data for our analysis comes from the study of 210 projects in the automobile industry between 1980 and 1991, although the principles we discuss should apply to any industry where firms compete with multiple product lines and where the sharing of components among more than one distinct product is both possible and desirable.

Many studies in the past have examined effective and efficient management practices for individual product development projects, focusing on such output measures as lead time, productivity, quality, and market share success (Myers and Marquis, 1969; Rothwell *et al.*, 1974; Zirger and Maidique, 1990; Cordero, 1991; Clark and Fujimoto, 1991). At the same time, various studies have suggested that leading manufacturers in various industries tend to introduce more new products more quickly than less successful competitors and that this capability allows them to respond more effectively to changes in technologies and customer tastes, as well as to fragmented customer segments (Abegglen and Stalk, 1985; Womack, Jones and Roos, 1990; Sanchez, 1995). The combination of these two types of potentially related capabilities—the ability to manage individual projects effectively, and the ability to leverage new technologies and introduce many new products quickly—should provide firms with a potent competitive formula (Garud and Kumaraswamy, 1995; Sanchez, 1995). This is especially true if product development represents a differentiating or 'core capability' of a firm (Wernerfelt, 1984; Prahalad and Hamel, 1990).

In recent years, other authors have also noted the strategic importance of planning for and managing the evolution of a sequence of new products (Wheelwright and Clark, 1992; Meyer and Utterback, 1993; Garud and Kumaraswamy, 1995). Researchers have discussed issues such as the benefits of leveraging a distinctive product platform among multiple product lines (Wheelwright and Sasser, 1989; Wheelwright and Clark, 1992) as well as the usage of core technologies (Meyer and Utterback, 1993) among derivative projects. Garud and Kumaraswamy (1995) have discussed the value for firms of developing new products by combining existing core technologies with the gradual introduction of new components in a way that enables firms to enjoy what the authors call the 'economies of substitution.' Cusumano (1991) as well as Markides and Williamson (1994) also refer to 'economies of scope' in new product development, although this sharing of technology is beneficial to a firm only when it results in competitive new products.

Despite this growing recognition of the importance of technology transfer and sharing in new product development within a single firm, previous researchers have not offered much in the way of specific strategies for leveraging technologies among multiple projects, nor have they done much to measure the quantitative impact of sharing strategies on market performance. This study, in contrast, identifies specific strategies for multiproject management and offers data on their market impact. In addition, we highlight two related, critical issues that other researchers have largely ignored.

First, we propose that the *speed* with which a firm can transfer component technologies from one project to another may have a significant impact on the competitiveness of a firm's product lines. This is because transferring old technologies may provide a firm with no advantage; it may even be a disadvantage and result in unsuccessful products and thus no scope economies across multiple projects (Markides and Williamson, 1994).

Second, we propose that *strategic planning* is important to transfer component technologies and effectively utilize them in more than one product. This planning involves technical issues such as product family architectures and component modularity, as well as organizational issues such as the allocation of engineering resources and the structuring of design work (Sanchez, 1995; Garud and Kumaraswamy, 1995). We believe, for example, that it is particularly useful for firms to schedule projects that are sharing components so that they overlap chronologically; this makes it possible for engineers to overlap tasks and thus design components for more than one product but still be able to adapt their designs as the products evolve (Nobeoka, 1993). Other studies have reported that the ability of engineers to make mutual adjustments when necessary can lead to greater efficiency and effectiveness in transferring technology from upstream functions to downstream functions (Leonard-Barton, 1988; Clark and Fujimoto, 1991). The same benefits should apply to technology leveraging among multiple projects.

We have organized this paper as follows. First, we offer a typology for laying out different multiproject strategies and discuss hypotheses regarding the relationship between these strategies and market performance. Second, we analyze data from 210 new products introduced by 17 automobile manufacturers between 1980 and 1991. The data analysis indicates that high performers (measured by sales growth) more often utilized what we call a 'rapid design transfer' strategy. We conclude by discussing the implications and limitations of this study.

FRAMEWORK: A TYPOLOGY FOR MULTIPROJECT STRATEGY

Multiproject strategy and management need to consider both the linkages between different product lines (interproduct line linkages) and the linkages between past and present projects (evolutionary linkages). One of the primary themes in existing literature that deals with interproject linkages is the distinction between radical innovation and incremental change (Ettlie, Bridges and O'Keefe, 1984; Dewar and Dutton, 1986; Kleinschmidt and Cooper, 1991; Banbury and Mitchell, 1995). In the same stream of research, there is a body of literature that has focused on the effects of the relatedness or newness of a project's task requirements compared to a firm's existing competencies in technology and marketing (Johnson and Jones, 1957; Abernathy and Clark, 1985; Meyer and Roberts, 1986).

The dichotomy between radical and incremental changes has provided some useful insights regarding the effectiveness of product development strategy. For example, while products with completely new technologies may sometimes enable firms to be first and thus monopolize a new market, products derived from related technologies with incremental changes can help sustain a firm's position in an existing market (Hollander, 1965; Banbury and Mitchell, 1995). Furthermore, new products based on technologies related to existing products often provide a firm with a better chance to grow than products based on technologies unfamiliar to the firm (Meyer and Roberts, 1986).

Whether a product's technology is new or related to existing products is useful to know, but it is a simplistic distinction. It does not help researchers and managers characterize and evaluate alternative strategies for leveraging key technologies among multiple projects. Nor does it help researchers and managers understand whether or not a firm's product development strategy is effective for an entire product portfolio that covers multiple generations of products and multiple product lines. In contrast, this study identifies two other critical issues related to the sharing of technologies among multiple projects: the specific application and the timing of technology leveraging.

Technology leveraging application

First, firms can leverage key technologies from existing products in two different ways (Sanchez, 1995). They can use existing technologies in a product redesign or replacement project. In other cases, firms can transfer the technologies to another product line that targets a different market segment from the original product. In the first case, firms try to enhance the competitiveness of their original product. In the second case, they try to extend their investment to move into a new market segment and achieve economies of scope in development. Both applications involve incremental changes, but they have vastly different implications on market competition at the corporate level. We can best analyze the impact of these incremental changes by separating the effects of the simple product enhancement strategy (i.e., technology leveraging within the same product line) from the economies of scope strategy (i.e., technology leveraging to create or enhance another product line).

Technology leveraging timing

Second, timing in the exploitation of existing technologies should be another critical factor that affects a firm's competitiveness. The technology that a firm modifies and exploits may be nearly obsolete or still relatively new. It is reasonable to assume that even competitive technologies eventually become outdated as time passes. Therefore, if a firm is going to utilize the same technologies in different products, how fast it can accomplish this transfer should affect how products do in the marketplace. There have been numerous studies focusing on the scope strategy (Teece, 1980; Goldhar and Jelinek, 1983; Clark, 1989). But researchers have all but ignored the timing of reuse activities or technology transfers among multiple projects.

The timing of technology leveraging also has significant organizational implications, both at the level of project management and at the level of corporate-wide structures and processes for managing engineering work. For example, a newly established project might try to borrow new components from another ongoing project that started before it did. In this case, engineers from the 'lead project' that is developing the new component technology can interact with engineers from the follow-on project and make adjustments in their designs if needed because the two projects overlap chronologically. When there is no chronological overlapping between projects, engineers cannot coordinate their work or make mutual adjustments in their designs, which might be necessary to avoid compromises in the performance of the product that relied on technology borrowed from the lead project.

Multiproject strategy typology for leveraging core technologies

Figure 1 presents a multiproject strategy typology focusing on interproject linkages for leveraging core technologies, such as a major component in a new product that defines its basic structure and performance. This typology categorizes new product development projects into four types, depending on the extent of changes, technology application purposes, and the timing of technology leveraging. These four types cover all types of new product development projects, and they are mutually exclusive.

Our analysis focused on the design strategy for vehicle 'platforms' in new car projects, although the same framework should apply to major components for other products as well. A car platform primarily consists of the floor panels, suspension system, 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 and the type and size of the drive train (engine and transmission). Industry engineers, as well as researchers studying the industry, generally consider the platform design to be the 'core subsystem' of the automobile. The selection of a specific platform also determines the general level of design functionality and sophistication of the whole product; for example, the platform for a sports car should differ significantly from the platform for a family sedan, even if both products are in the same vehicle size category. In addition, the platform technology is one of the key areas in which most automobile manufacturers compete as they introduce new designs and strive for higher levels of performance. Developing a new platform design also requires more financial and engineering resources than any other automobile component, with the possibe exception of a totally new engine.

The extent of change required in a new project determines whether its core design (such as the platform design) is newly developed or transferred and modified from another project. We categorize new projects that develop platforms primarily from scratch without a preexisting base design as the first type, *new design strategy*. This strategy is most appropriate for creating a new core technology by incorporating the latest technology or totally new designs into a new product without placing many restrictions on the development team. The distinction between new design and the other three types is conceptually similar to the difference between radical and incremental innovations (Dewar and Dutton, 1986; Ettlie *et al.*, 1984; Kleinschmidt and Cooper, 1991). Our framework, however, breaks down incremental changes into three types, depending on the strategy for technology leveraging.

The next two types of projects transfer and share a core technology and 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 (generally, within about 2 years of platform completion, as discussed in the next section). Because some of the development phases overlap chronologically, mutual adjustments in design between the new project and the base project are possible and likely. This overlap, therefore, may lead to effective and efficient design transfer between the two projects. In order to implement this strategy, however, these two projects may require extensive coordination and a particular organizational or project management structure.

The third type, *sequential design transfer*, transfers a design from a base model to a new

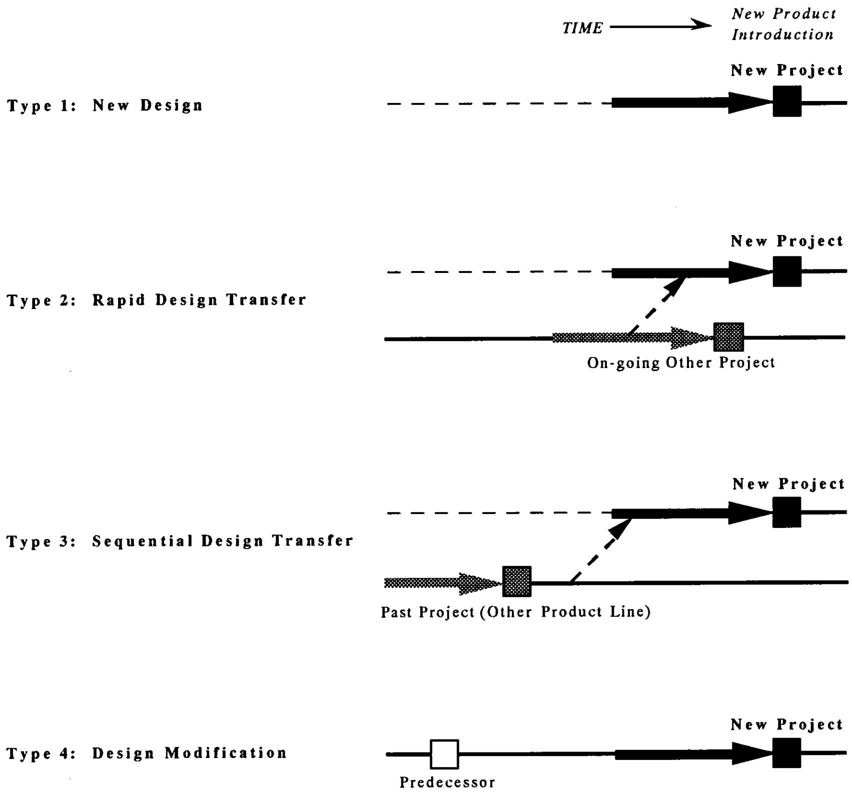

Figure 1. Typology of project strategies

product after a previous project has finished developing the base model. This type of project often reuses an existing design that is 'off-the-shelf'. The transferred design is already relatively old compared to designs transferred while a base model is being developed, as in rapid design transfer. In addition, constraints may still be high in sequential design transfers because mutual adjustments of the core design between the projects are no longer possible. In other words, the following project may have to force changes to accommodate elements of the core design and other components from the older product. This may result in too many design compromises and insufficient product integrity. Thus, sequential transfers may not be efficient or effective, compared to rapid design transfers. (This discussion of 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 enables mutual adjustments; see Thompson, 1967).

The last type, *design modification*, refers to a project that replaces an existing product and contains a core design inherited from the predecessor product. This type of project cannot have any ongoing interproject coordination with a base project either, and has to consider constraints from the core design of the predecessor product (i.e., the current model). The difference between design modification and sequential design transfer is the source of the base design and its application.

HYPOTHESIS: IMPACT ON MARKET PERFORMANCE

In addition to the interproject linkages discussed above, the new product introduction rate is a critical company-level output metric directly related to multiproject strategy. The new product introduction rate measures the frequency of new products within each firm. We define this as the ratio of the number of new product introductions adjusted by the number of product offerings in a base year. We believe that firms which introduce more new products (i.e., that have a higher new product introduction rate) should increase sales more over time than their competitors. This thinking is consistent with other studies suggesting that frequent product introductions have a positive influence on sales growth. This is because a higher new product introduction rate makes it possible for a firm to replace existing products more quickly, or to broaden their product lines more quickly than competitors (Miller, 1988; Fujimoto and Sheriff, 1989; Kekre and Srinivasan, 1990; Sanchez, 1995). Broader product lines may enable a firm to grow and meet consumer needs more effectively by covering a wider range of market segments or by enabling each product to focus more effectively on specific market niches (Bagozzi, 1986; Kotler, 1986; Bower and Hout, 1988).

The impact of the new product introduction rate on market performance may be particularly important in industries such as automobile production, where two general conditions seem to hold: first, the technology improves steadily in small increments, instead of through radical improvements only once in a while, and marginal superiority is the basis for product competition in the marketplace; and second, customer expectations are fragmented and change at a rapid pace, predicated by current fashion trends and social values; therefore, 'freshness' in styling and model introduction, in addition to performance functionality, has a significant influence on sales (Clark and Fujimoto, 1991). These observations lead to our first hypothesis:

> *Hypothesis 1: In periods when firms develop a large number of new products (i.e., when they have high new product introduction rates), they should exhibit greater increases in sales compared to periods when they introduce fewer products (i.e., when they have lower new product introduction rates).*

The next question is which type of multiproject strategy is the most appropriate to develop a number of new products. One of the primary goals at the corporate level for new product development may be not only to introduce new component technologies and designs into a single product line, but to introduce them as quickly as possible into a family of product lines targeting different market segments. Firms may achieve this by developing new and unique designs for all their individual product lines separately, using the *new design strategy* for every new product. However, projects that develop more new components generally require more lead time and engineering resources (Clark and Fujimoto, 1991; Nobeoka and Cusumano, 1995). Otherwise, frequent new design introductions may reflect incomplete development efforts and result in products that suffer from problems in design quality and perform poorly in the marketplace (von Braun, 1991). An exclusive use of the new design strategy, therefore, may result in either too few new product introductions or weak new products. This strategy may be effective in preserving the market competitiveness of an individual product line, and may result in one or more new 'hit' products. On the other hand, it does little to help a firm systematically improve or expand its *portfolio* of products.

Automobile firms often try to develop more new products or better products than their competitors without relying on old technology. For example, one of Clark and Fujimoto's findings implied that, in order to avoid a trade-off between new designs and reused designs, some of the successful Japanese manufacturers depended more on outside suppliers for new components (Clark, 1989; Clark and Fujimoto, 1991). Our study explores the idea that successful manufacturers may also have multiproject strategies that differ from those of low performing manufacturers in order to mitigate this trade-off.

If firms want to utilize their investments effectively and still maintain a high new product introduction rate, then they may try to decrease the number of new components in each project and carry over substantial portions of existing designs—that is, reuse existing core technologies as often as possible (Garud and Kumaraswamy, 1995). This is similar to how 'flexible' factories in software and other industries assemble different products from standardized parts or modules (Cusumano, 1991). Particularly when specific technologies reflect a firm's 'core competencies', managers may want to utilize these technologies quickly in a wide range of end-products (Prahalad and Hamel, 1990). Meyer and Roberts (1986) also found that firms which stick to core technologies and leverage these in multiple new products grew faster in sales than companies which developed new technologies for each of their new products.

Extensive usage of rapid design transfer or sequential design transfer may provide firms with a greater advantage in leveraging their competencies and engineering investments than the other two multiproject strategy types. However, a new product based on sequential design transfer by definition incorporates relatively older technologies than products based on rapid design transfer. Repeated use of old components may then have a negative impact on market competitiveness. For example, one reason for frequent new product introductions is to meet changes in customer tastes and needs with new technologies and designs. Reusing an old design may conflict with this objective. It may also impose constraints on introducing new designs for other components. In contrast, the rapid reuse or transfer of new technologies and designs among multiple ongoing projects may improve the average level of newness and technological sophistication of a firm's overall product offerings.

In recent years, many authors have also written about the importance of 'time to market' for individual products. As mentioned above, however, we believe that another critical issue is *speed in technology leveraging*. This refers to the time a firm requires to develop and then transfer key technologies among multiple projects in order to deliver new products or replace existing products. In short, firms may best utilize new technologies and designs across multiple projects by quickly transferring them while these technologies and designs are still relatively new in the market as well as in the company.

There is also an organizationl advantage to rapid rather than sequential design transfer. Only by coordinating chronologically overlapping projects can a firm transfer a design from a base project to a new project and facilitate task sharing among engineers as well as mutual adjustments and communication between the interdependent projects. This is similar to overlapping different functions within a single project through simultaneous or 'concurrent' engineering, which can enhance both the speed of a project and the quality of the final output (Clark and Fujimoto, 1991). Concurrent multiple projects should be beneficial for both the speed and the effectiveness of technology leveraging between projects (Nobeoka, 1995).

Finally, focusing on design modifications may not be advantageous to a firm either in terms of design leveraging or the creation of new core technologies. Under this strategy, a firm enhances an existing design relatively slowly over multiple generations of the same product. It does not take advantage of new technology developed in other product lines. Only when we consider an individual project for a particular product line does the design modification strategy seem to be effective. In our framework of multiproject strategies, however, this strategy may be the least effective for predicting a firm's growth rate in sales. These ideas lead to the next two hypotheses:

> *Hypothesis 2: A firm that utilizes the rapid (or concurrent) design transfer strategy for a larger portion of its new products should increase sales more than firms emphasizing the other three strategies.*

> *Hypothesis 3: A firm that utilizes the design modification strategy for a larger portion of its new products should exhibit lower sales increases or larger sales decreases than firms emphasizing the other three strategies.*

SAMPLE AND MEASUREMENTS

The sample in this study covers the 17 largest passenger car manufacturers in the world. They consist of five Japanese (Toyota, Nissan, Honda, Mazda, Mitsubishi), three U.S. (General Motors, Ford, Chrysler), and nine European producers (Volkswagen–Audi Group, Mercedes Benz, BMW, Opel, Ford of Europe, PSA, Renault, Fiat Group, Volvo).[1] These firms introduced, in total, 210 new car products to the international market, including the United States, Europe, and Japan, between 1980 and 1991. Because this research focused on a firm's internal capabilities for developing and introducing mass-production cars, we excluded 'special off-line' and 'externally developed' products.[2]

[1] VAG: VW and Audi; PSA: Peugeot and Citroen; Fiat Group: Fiat and Lancia. Data for Alfa Romeo are not included in the Fiat Group because it became a part of the Fiat Group in November 1986.

[2] In this research, we do not count 'special offline' products such as the Toyota Sera, the Dodge Viper, the Honda NSX,

We collected data on new products primarily from *Automobil Revue*, an industry journal annually published in Switzerland. This covers introduction dates and design feature details for all new car products worldwide. We also referred to automobile magazines including *Motor Trend*, *Car and Driver*, *Car Graphic*, *NAVI*, and *Car Styling*, as well as a weekly industry journal, *Automobile News*, for detailed information on projects. To develop a methodology to categorize the 210 new car projects into different strategies, and then to validate the methodology, we also conducted interviews with approximately 130 engineers and 30 project managers, primarily from Toyota, Nissan, Honda, Mitsubishi, Mazda, General Motors, Ford, Chrysler, Fiat, Volkswagen, Renault, and Mercedes.

We divided the data into four 3-year time periods: 1980–82, 1983–85, 1986–88, and 1989–91. The 17 firms and four time periods make 68 combinations or data points. Among the 68 combinations, we did not use three because they referred to three firms that introduced no new products during one of the four time periods. As a result, our final sample consists of 65 data points describing company-level strategies and sales growth.

We chose the scheme of four 3-year periods because we believe that longer or shorter periods both present problems. For example, a longer interval, such as two 6-year periods, may create a causality problem because 6 years is enough time for firms to choose a product strategy for the later years that directly reflects their market performance within the earlier years of the same period. On the other hand, we believe that a shorter period, such as 2 years, is not long enough to capture the effects of a dynamic multiproject strategy and thus is not conceptually appropriate for this research framework. In contrast, 3-year periods are long enough for the influence of firm strategies to appear in the market because the sales peak for new car products is usually recorded within the first year after introduction. Thereafter, sales usually decline gradually. (We also calculated the timing of new product introductions in the analysis from 6 months after the official introduction of the products to the market because it often takes several months for the production, distribution, and sale of new products to reach target levels.) Nevertheless, in order to detect any serious bias resulting from the 3-year period scheme, we conducted sensitivity tests using other time periods, and found no significant changes in the results.

Sales growth

We calculated sales growth using estimates of revenues for each product in North America, Japan, and Europe. We determined revenues by multiplying the total unit production for each product by an average sales price. We collected the production data from a single source, *Motor Vehicle Statistics in Major Countries* (Japan Automobile Manufacturers Association), to maintain consistency. Sales growth is the percentage change in a company's car sales revenues from the beginning of one 3-year period to the end of the same period.

The average sales prices we used were those in the U.S. market, adjusted to 1991 prices. For products not available for purchase in the U.S. market, we estimated prices from equivalent products in the U.S. market with respect to size and equipment levels. This methodology is similar to using purchasing power parity rather than exchange rates, and minimizes the impact of changing exchange rates.

New product introduction rate and definition of a new product

We calculated the new product introduction rate for each manufacturer during each of the 3-year periods by taking the number of new product introductions and dividing this by the number of product offerings in the base year. We defined a new product as a car newly introduced with mostly new interior and exterior styling, as opposed to a product with a minor facelift or a

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the Nissan PAO, or the BMW Z1, whose production volume is approximately 0.5 percent or less of a firm's total car production volume. These products are not usually developed with the same level of production preparation or development standards as mass-production models. New products whose platforms are primarily developed externally are also excluded. For example, the 1989 Mazda Carol and the 1987 Ford Probe were excluded from this study because the platform of the 1989 Mazda Carol was developed by Suzuki and that of the 1987 Ford Probe was developed by Mazda. Including products developed or sold through alliances would have added only about 10 products to the sample of 210. In addition, more than half of these products are nearly identical to other products covered in our sample and are sold under a different company label on an OEM basis.

variation that consists of minor cosmetic modifications.[3] This analysis focuses on the management of multiproject strategies and interproject organizational interactions, rather than the development of minor product variations such as multiple body types. Therefore, we counted as only one the new product variations designed within a single project led by a single project manager, such as the Taurus and the Sable at Ford, or product variations developed within a multibrand project like the General Motors GM10 project (sold under the Pontiac Grand Prix, Oldsmobile Supreme, Buick Regal and Chevrolet Lumina brand names).

Usage of different multiproject strategy types (%)

We measured usage of different multiproject strategies by determining the percentage of the different types of new car products introduced by a firm during a 3-year period. For example, if a firm introduced 10 new products during a 3-year period and three of these new products were rapid design transfers, we calculated the usage of the rapid design transfer strategy during this period as 0.30 or 30 percent. As this example implies, usage of different multiproject strategies is particularly meaningful when analyzed in conjunction with the new product introduction rate.

In order to determine whether a firm newly developed or transferred the platform of a new product from a preceding product, we developed a point scheme through consultation with industry engineers (see Appendix for the point scheme). Through this methodology, we were able to categorize product strategies using publicly available data on product specifications. We assigned points according to the extent of changes in platform technology and design between the new product and related preceding products based primarily on changes in the wheelbase and tracks as well as the suspension. These measurements cover the extent of changes to the platform, which consists of floor panels, the underbody structure, and the suspension system.

We believe that analyzing all new products introduced during this time period using a systematic methodology based on public data was better than relying on the subjective opinions of engineers involved in a sample of projects. We did not consider it practical or necessary to interview engineers for the entire set of 210 projects. Some projects had ended more than 10 years ago, and most products were relatively easy to classify. Nonetheless, during the course of our research, we relied on interviews with approximately 45 engineers and program managers to help us validate our point scheme as well as check the specific points we assigned to particular products. We also made a list of the half-dozen or so products that were difficult to classify from the public data and directly asked company engineers and program managers to help us categorize them.

We categorized projects that develop new platform designs without any preceding base design as following a new design strategy. Among projects derived from an existing platform, we categorized those which develop a new product based on the platform design of the predecessor model as design modifications. We categorized products that shared platform designs with any preceding projects for other product lines as either rapid design transfers or sequential design transfers. We determined the distinction between rapid and sequential transfer by the transfer time lag.

We defined rapid design transfers as projects where the transfer from a base project occurred within 2.0 years of the introduction of the base design. Our interviews with company engineers indicated that, if the time lag is shorter than this, then there are always interactions or coordination efforts between a base project and a new project. In our definition, a key factor that conceptually differentiates rapid design transfer from sequential design transfer is whether an overlap in platform design activities exists between the new project and the base project. Two years is also close to the midway point (2.2 years) for the average lead time for a new car development (54 months, or 4.5 years), as calculated by Clark and Fujimoto (1991: 73).

We also sent a questionnaire survey to project managers in Japan and the United States. Results from this support the 2-year cut-off point as well

[3] Major components for exterior styling include doors, fenders, pillars, roofs, bumpers, windshields, hoods, trunk lids, hatchback doors, front grills, and exterior moldings. A new exterior styling means that all of these components are new. The same idea applies to changes in interior stylings. In the automobile industry, particularly in Japan and Europe, it is usually clear whether a new product is actually a 'new product' or a 'facelift product'. For example, Japanese industry people (and customers) clearly distinguish these two by referring to them as 'major-change' projects and 'minor'change' projects, respectively.

(see Nobeoka and Cusumano, 1995). According to our survey data, platform design transfer between multiple projects within 2.0 years was always associated with ongoing interactions between a base project and a new project. Those projects with a transfer lag between 2.0 years and 3.0 years show mixed results: some projects have interactions with a base project and some do not. No project derived from a base project with delays of 3.0 years or longer had any interactions with the base project. These data included projects both in the United States and in Japan, and there was no regional difference evident. Nevertheless, we also tested the sensitivity of the 2.0 year division by using 1.5 years and 2.5 years as cut-off points, with no changes in the results (see our later discussion).

Examples of different multiproject strategies

Because the categorization scheme of product strategies plays a key role in this study, we cite the following examples to illustrate each of the four multiproject strategies.

New design

In most cases, it was easy to identify new designs because firms often adopted new technologies for their platforms during the period of our study (1980–91). Some products changed from rear-wheel drive to front-wheel drive, and others introduced new suspension technologies such as multi-link or compact double-wishbone systems. To incorporate such major changes requires completely new platform designs.

For example, the new 1987 Civic project developed wide product variations including the basic Civic, the CR-X (three-door coupe), and the Shuttle (five-door hatchback). We counted all of these variations as one product because a single project team developed all of them (see *Car Styling*, Vol. 61, November 1987, p. 78). *Automobil Revue* (1984 and 1989) described the suspension system and the chassis of the previous product, the 1983 Civic, and the 1987 Civic, as follows:

> 1983 Civic: Integral body; front independent suspension with McPherson struts, front lower A-arm and torsion bar spring, some models with antiroll bars; rear trailing arm, torsion beam axle and Panhard rod with strut, semi-rigid. Some models with antiroll bars. (1984: 300).

> 1987 Civic: Integral body; all-round independent suspension with coil springs and air adjustable shock absorbers, front upper A-arm, lower control arm and coaxial tension struts; rear trailing arms, swinging arm, with upper and lower control arms. Some models with front and/or rear antiroll bars. (1989: 313)

The suspension system in the new Civic is a variation of the four-wheel double-wishbone type. The older Civic uses a variation of McPherson strut types in the front and a variation of semi-independent torsion bar types in the rear. The new Civic has a completely different system compared to either the 1983 Civic or any other existing designs at that time in Honda. This platform was technically innovative because no other products of this size had a double-wishbone suspension. The wheelbase/tract for the new Civic four-door sedan and the old Civic four-door sedan are 2450/1400 mm and 2500/1450 mm, respectively. The difference in both the wheelbase and track of the new and the old Civic indicates that the floor panels for the new Civic are also new. Therefore, we categorized the 1987 Civic as a new product under the new design strategy.

Rapid (or concurrent) design transfer

In May 1988, 13 months after introducing the 1987 Civic with a completely new platform, Honda introduced a new product line, the Concerto. The Concerto project and the Civic project were organizationally separate and managed by different project managers. The Concerto project developed two different body variations. The Concerto had exterior and interior stylings that were completely different from any variations of the 1987 Civic. However, the Concerto's suspension system is identical to the 1987 Civic (*Automobil Revue*, 1990). The Concerto sedan's wheelbase is 2550 mm, 50 mm longer than that of the Civic sedan, while the Concerto's front track is identical to the Civic sedan. Therefore, we concluded that the Concerto project shared the same platform as the Civic but stretched the wheelbase by 50 mm. Because Honda introduced the Concerto only 13 months after the Civic project, we categorized the Concerto project as following the rapid design transfer strategy.

Sequential design transfer

Chrysler primarily relied on sequential design transfers to introduce new products during the 1980s. It began in September 1980 with the K-car project. This developed and introduced a completely new platform for the front-drive Dodge Aries and the Plymouth Reliant. *Automobil Revue* (1982) described the chassis of this platform as follows:

> Integral body. Front McPherson struct and A-arm; rear rigid axle with trailing arm and Panhard rod, front and rear coil sprints, telescopic damper and antiroll bar. (1982: 274)

Chrysler then used this platform as a base for several other distinctive products. These include the 1985 H-car project (the Dodge Lancer and the Chrysler LeBaron GTS), the 1987 P-car project (the Dodge Shadow and the Plymouth Sundance), and the 1988 C-car project (the Dodge Dynasty and the Chrysler New Yorker). For example, the P-cars, introduced in March 1986, employed exactly the same chassis specifications and the same front track, 1460 mm, as the original K-cars (*Automobil Revue*, 1987: 462). Because the wheelbase of the P-cars (2465 mm) is 75 mm shorter than the K-cars, we concluded that the platform of the P-car is a shortened version of the K-car platform. The platform design of the P-cars at the introduction date was already 5.5 years old (the time difference between September 1980 and March 1986). Because it is longer than 2.0 years, we categorized the P-car project following the sequential design transfer strategy.

Design modification

In 1987, Toyota introduced a new Corolla. We categorized this project as following the design modification strategy. Product body variations of this Corolla included the basic Corolla, the FX, the Levin, the Sprinter, the Cielo, and the Trueno. Again, we counted all these variations as one product because Toyota developed all of them within one project. *Automobil Revue* (1989) described the chassis (platform) design of the new Corolla as follows:

> Integral body, front and rear independent suspension with McPherson struts, front lower A-arm, rear parallel control arm and trailing arm, front antiroll bars, some models also rear antiroll bars. (1989: 554)

Automobil Revue (1987) also described the suspension system in the previous model, the 1983 Corolla; this is identical to the description for the new 1987 Corolla. With respect to the change in floor panels, we compared the wheelbase and track dimensions of the 1983 Corolla and the new Corolla and found that they are the same (2430 mm and 1430 mm, respectively). Because the new Corolla and the old Corolla shared the same suspension system and the same wheelbase/track, it is relatively obvious that the new Corolla used the platform of the old Corolla at least as a base. Therefore, we consider the new Corolla as a design modification project. The platform design of the 1987 Corolla was already 4.0 years old when Toyota introduced it in May 1987.

Trend of project characteristics in the sample

Table 1 shows the trend of the total number of new product introductions and the number and the percentage of each multiproject strategy type during each period. The total number of new product introductions increased rapidly after 1989, from 50 in 1986–88 to 61 in 1989–91. Use of the rapid design transfer strategy also increased sharply in the middle of the 1980s, from 6% in 1983–85 to approximately 20% in 1986–88 and 18% in 1989–91. The increase in the rapid design transfer strategy reflects the accelerating speed with which firms have been leveraging new platform designs to other product lines. The adoption of rapid design transfer also implies that managing multiple overlapping projects, as opposed to managing one project at a time, has become more important to automobile manufacturers. In fact, the percentage of rapid design transfer, about 20 percent during 1986–91, means that firms had to coordinate almost 40 percent of all projects. This is because each rapid transfer requires, by definition, overlapping with at least one other project from which the platform design originates.

ANALYSIS AND RESULTS

The data included both cross-sectional (17 firms) and time-series (four periods) components. Pool-

Table 1. The number of projects introduced by sample firms

Strategy type	Period				Total
	1980–82	1983–85	1986–88	1989–91	
New design	27 (57%)	26 (50%)	24 (48%)	29 (48%)	106
Rapid design transfer	4 (9%)	3 (6%)	10 (20%)	11 (20%)	28
Sequential design transfer	8 (17%)	14 (27%)	9 (18%)	11 (18%)	42
Design modification	8 (17%)	9 (17%)	7 (14%)	10 (14%)	34
TOTAL	47 (100%)	52 (100%)	50 (100%)	61 (100%)	210

ing observations for each firm violates the assumption of independence required for ordinary least-squares regression. In order to rule out the effects of unmeasured firm differences in the analysis of the panel data, we estimated fixed-effects models, introducing one dummy variable for each firm and eliminating the constant. In these models, all cross-firm variation is captured in the estimates of the dummy variables. The fixed-effects model assumes that each firm has its own intercept, and firm-specific effects are fixed over time. We also estimated an alternative model, the random effects model, which assumes that firm-specific effects are random variables. Because there are no significant differences in results between these two models, we report those from the fixed-effects model. In addition, we computed the heteroskedasticity-consistent standard errors for the regression coefficients, using procedures discussed by White (1980). This test computes standard errors that are consistent even in the existence of unknown heteroskedasticity.

We also designed the fixed-effects model to correct for autocorrelation of errors for individual firms over time. First, the dependent variable was assessed as the percentage change. Second, dependent variables in a prior period (t–1) was added as an independent variable. Third, we added three dummy variables to represent three of the four periods to control for time effects. These treatments usually ease autocorrelation problems. As a result, residuals for each firm in our regression models did not show any signs of autocorrelation in our visual observation of a residual plot for predicted values.

Consequently, in addition to firm dummy variables in the fixed effects model, we also introduced some other control variables including market coverage, sales growth in a prior period, and four different time periods. We measured market coverage by the number of product offerings throughout world markets for each firm at the beginning of each period primarily to control for firm size.

Table 2 shows descriptive data and a correlation matrix for major variables. The average sales growth across all manufacturers is 0.052 or 5.2 percent. The new product introduction rate, on average, is 0.518. This number means, for example, if a firm focused only on replacing existing products with new products, it would have replaced about half of all its products during any of the 3-year periods we considered.

Table 2 also indicates that the new product introduction rate has a significant correlation with sales growth (0.45, significant at $p<0.01$). An analysis of sales growth and the use of each of the different multiproject strategies indicates that only an extensive use of rapid design transfer has a significant positive correlation with sales growth. An extensive use of design modification has a negative correlation.

Table 3 presents results for the fixed-effects regression analyses for influences of different multiproject strategies on sales growth. Model 1 contains the control variables without any multiproject strategy variables. Model 2 adds the new product introduction rate. Model 3 has both the new product introduction rate and the multiproject strategy variables. As our first hypothesis sug-

Table 2. Descriptive data and correlation matrix (N=65)

	Ave.	S.D.	1	2	3	4	5	6	7
1. Sales growth change	0.052	0.249	–						
2. New product introduction rate	0.518	0.308	0.45***	–					
Multiproject strategy type									
3. New design	0.563	0.354	0.03	–0.08	–				
4. Rapid design transfer	0.099	0.180	0.29**	0.23*	–0.18	–			
5. Sequential design transfer	0.191	0.294	0.05	–0.01	–0.65***	–0.25**	–		
6. Design modification	0.147	0.246	–0.32**	–0.05	–0.54***	–0.17	–0.09	–	
7. Market coverage	6.62	2.73	–0.14	–0.24*	–0.28**	0.04	0.13	0.23*	–
8. Sales growth change (t–1)	0.105	0.235	–0.20	–0.14	–0.03	0.33***	–0.08	0.11	–0.13

*$p<0.10$; **$p<0.05$; ***$p<0.01$

gests, the new product introduction rate significantly predicts differences in sales growth even after controlling for other relevant factors. The results also support the second and third hypotheses. In the model, extensive use of rapid design transfer has a strong positive influence on sales growth. On the other hand, design modification has a significant negative influence on a firm's sales performance.

We conducted various tests to examine the sensitivity of our data and analysis schemes. First, we conducted two additional analyses using samples separately excluding the second and then the third periods. This analysis also tried to detect any autocorrelation problems. Second, we ran sensitivity tests for different data-processing schemes, using two other alternative methods for period divisions: three 4-year periods and two 6-year periods. Finally, we tested two alternative cut-off points betwen the rapid design transfer strategy and the sequential design transfer strategy: 1.5 years and 2.5 years. There are no major differences in the results using these alternative methods.

We realize that the variables we used to predict market performance have limitations. Our primary purpose in this section was not, however, to develop a comprehensive model to predict sales performance. Selling products is a complex phenomenon, and ultimately results from the ability of a firm to design, build, and market products that customers want to buy. This relates to quality, price-performance, advertising, product availability, service, and numerous other factors.

Nonetheless, we believe that we have highlighted an important strategy for the management of product development—that of rapid design transfer. Our data demonstrate that even a limited

Table 3. Regression results for sales growth

Independent variables	(1)	(2)	(3)
New product introduction rate		0.435*** (0.160)	0.456*** (0.145)
Multiproject strategy (%)			
New design			–
Rapid design transfer			0.510*** (0.185)
Sequential design transfer			0.125 (0.091)
Design modification			–0.321** (0.128)
Market coverage at beginning	–0.038* (0.021)	0.002 (0.019)	0.032 (0.024)
Sales growth change (t–1)	–0.415*** (0.148)	–0.352*** (0.130)	–0.330*** (0.105)
Period (dummy)			
1980–82	0.016 (0.077)	0.064 (0.066)	0.080 (0.061)
1983–85	–0.106 (0.080)	–0.069 (0.074)	0.271** (0.075)
1986–88	0.008 (0.078)	0.036 (0.072)	0.148* (0.062)
1989–91	–	–	–
Adjusted R^2	0.186	0.312	0.510

Heteroskedasticity-consistent standard errors are in parentheses (White, 1980). All results are for a fixed-effects model and therefore include 16 firm dummy variables.
$^*p<0.10$; $^{**}p<0.05$; $^{***}p<0.01$; two tailed tests.

number of variables related to multiproject strategy can explain a substantial portion of sales growth. (The adjusted R^2 is 0.510 for the full-variable model in Table 3, as compared to 0.312 for the model without the multiproject strategy variables).

DISCUSSION AND CONCLUSIONS

In order to increase sales, it seems useful for firms not only to develop new designs but, at the same time, to leverage these new designs quickly in overlapping projects that produce other new products. This strategy of rapid or concurrent design transfer appears to help firms grow sales more quickly compared to alternatives where, for example, firms develop new products one at a time or transfer designs slowly to other products in a sequential manner.

This finding is consistent with a study by Meyer and Roberts (1986), which found that firms developing image-processing technology that leveraged core technologies in multiple new products gained more in market share than companies which developed new technologies for each of their new products. A unique contribution of our study, however, is the finding that firms seem to do better if they leverage core technologies and designs across multiple product lines while these designs are still relatively new. In other words, not only the *application* of technology leveraging, but also the *speed* with which firms transfer new technologies across multiple projects, seems to have an impact on corporate-level performance.

This makes sense. New technologies often represent major investments for a firm and may also embody distinctive skills in research, design, engineering, or manufacturing. It may thus be extremely useful for a firm to leverage such investments in as many business units and product lines as possible (Prahalad and Hamel, 1990). Technology leveraging of this sort also supports concepts such as 'economies of scope' in design and engineering work (Goldhar and Jelinek, 1983; Cusumano, 1991, 1992; Kotha, 1995; Sanchez, 1995) as well as 'mass customization' (Pine, 1993) and 'economies of substitution' (Garud and Kumaraswamy, 1995) in product development and manufacturing more generally.

Rapid design transfers not only can help companies utilize their design and engineering investments more broadly. They may also help companies improve product quality and customer satisfaction by diffusing good new designs quickly across multiple products. Newer designs usually imply more up-to-date and sophisticated features than old designs. In addition, the standards of a 'good' design can change quickly in sophisticated markets such as the United States, Japan, and Europe. Because changes are fast in customer tastes and needs, competitive conditions, and current fashion trends, only products based on relatively new designs and technologies may consistently meet contemporary definitions of good design quality.

We think it is particularly important to emphasize the notion that *overlapping* projects, as in the rapid design transfer process, may help improve the quality and the effectiveness of technology leveraging. By definition in this study, only through rapid design transfers can new technologies be transferred between two projects with mutual adjustments and ongoing communications during the development process. If a firm waits until it completes a base project and then transfers the technology, it has to rely primarily on design drawings and specifications. In order to adjust designs to the specific requirements or context of a new product, however, engineers often need intangible knowledge, such as a detailed understanding of the design process for a particular component or the logic behind individual drawings and design decisions (Nobeoka, 1995). In addition, it may be impossible to transfer technical knowledge from relatively old projects if product architectures, components, engineering tools, and project personnel change too much over time.

If core technologies are modular or flexible enough to be used in different applications, then the problem regarding technology leveraging without mutual adaptation may not be too serious (Garud and Kumaraswamy, 1995; Sanchez, 1995). Nonetheless, problems are most likely to occur with slow sequential design transfers or design modifications, which do not allow engineers to make ongoing adaptations or to coordinate designs for multiple projects.

The rapid design transfers that we describe also seem to require a set of specific capabilities and to create certain risks. For example, a firm needs the ability to plan and implement long-term product strategies and build a coherent product portfolio. At the same time, a faulty new design might cause extensive problems if a firm quickly transfers this design across many products. In order to implement rapid design transfers, a firm may also need to concentrate its investments within a relatively short period of time in order to develop multiple related products concurrently. A firm may need new skills in project management or may need to hire more engineers and suppliers to achieve this.

It also seems clear to us that the effective management of multiple projects requires some capabilities, including particular organizational structures and processes, that are different from those used to manage single projects. For example, Clark and Fujimoto (1991) have argued that a 'heavyweight' project manager system and relatively autonomous project teams are important to optimize individual project performance. What is optimal for one project, however, may not be optimal for the firm in terms of developing and leveraging new technologies across many projects. Several project managers and project engineers may need to compromise or make joint decisions on designs. On the other hand, rapid design transfers between autonomous project teams may require those projects to make unwise compromises in their designs or cause too much additional time for coordination activities. Therefore, in order to benefit from rapid technology transfers, a firm needs to be able to manage concurrent multiple projects and at the same time to avoid compromises that unduly sacrifice the integrity or quality of individual products.

In conclusion, effective multiproject management may demand specific strategic planning and organizational capabilities that are more difficult to devise and implement than single project management. In particular, it seems to us that a firm cannot instantly acquire the necessary organizational skills. But firms that succeed in following the rapid design transfer strategy should see two benefits in performance. First, this strategy should facilitate the introduction of more new products and greater improvements in sales growth than other strategies we have identified. Second, rapid design transfer may be difficult to imitate since it involves a host of related efforts in investment patterns, project planning, and organizational coordination.

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APPENDIX: CHANGE INDEX OF PLATFORM DESIGN AND LIST OF PRODUCTS

Floor panels

Points	Description
0	*Same*. Both wheelbase and track are unchanged excepting variations of tire size and wheel offset.
1	*Partially new*. Only either wheelbase or track are new with considerations of tire size and wheel offset.
2	*New*. Both wheelbase and track are new with considerations of tire size and wheel offset.

Suspension technology and design

Points	Description
0	*Same*. Suspension system and design are unchanged.
1	*Partially new*. Suspension system is basically the same, but design is modified such as changing a shape of arms. Small modifications made only for the sake of *multiproduct line* applications are not considered as changes.
2	*New*. Suspension system is completely new (see variations of suspension types described below).

If the sum of the points from both areas is three or more, the platform design is defined as new. These points were reviewed based on interviews with about 45 engineers at Toyota, Nissan, Mazda, Mitsubishi, Honda, Ford, GM, Chrysler, Fiat, Renault, and VAG regarding the actual design changes made on the specific platform designs.