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Abstract

In automobiles and other industries most large manufacturers have several product lines and constantly develop new products to replace existing products or to add completely new product lines. Managing the way different projects relate to each other technologically is extremely important in helping a firm leverage its engineering and financial resources, as well as existing technologies and designs, across multiple projects. Nonetheless, there has been little research that explores multi-project management.

The purpose of this paper is to explore product-development strategies used in the management of multiple automotive projects. An underlying hypothesis is that differences in multi-project strategy should influence the effectiveness of an entire firm in new product development. This paper proposes a typology of multi-project strategies, which categorizes new product development projects into four types: *new design, rapid design transfer, sequential design transfer, and design modification.* Based on this typology, this paper examines the potential influence of different types of multi-project strategies on market competitiveness. Using data on 210 new products introduced by 17 worldwide auto manufacturers between 1980 and 1991, this paper argues that high performers (measured by market share growth) more often utilized a "rapid design transfer" strategy. Under the rapid design transfer strategy, new technologies and designs developed as part of one project are quickly transferred to other projects within the firm.

1 Introduction

Since the management of new product development has become a central issue in global competition, numerous academic researchers have undertaken studies of how effective and efficient new product development projects have been in various industries. Most of the empirical research has focused on managerial approaches and performance measures for new product development projects. Many studies have explored management factors that led individual projects to marketplace success (Myers and Marquis, 1969; Rothwell, et al., 1974; Zirger and Maidique, 1990). In many industries such as automobiles, however, large firms have at least several product lines and constantly undertake multiple development projects to add new product lines or to replace existing products. A firm's performance in the market is determined by the effectiveness of the management of the entire portfolio of new product projects within the firm. This study explores multi-project strategy within a firm, which includes policies for design transfers among multiple projects and inter-project linkages, and their impact on a firm's market performance measured by growth in revenues over time.

Because of the accelerating pace of change in technologies and customer needs, a number of recent studies have focused on lead time or the completion speed of individual projects (Clark and Fujimoto, 1991; Cordero, 1991; McDonough III and Barczak, 1991; von Braun, 1991; Crawford, 1992). At the same time, various studies report that leading manufacturers in Japan, in various industries, tend to develop and introduce more new products than U.S. or European competitors and that this frequency creates a competitive advantage because of the ability of the Japanese to replace existing products with new technology more frequently, and expand their offerings into increasing numbers of product segments (Abegglen and Stalk, 1985; Dertouzos et al., 1988; Womack et al., 1990; Smothers, 1990). The second body of studies has primarily focused on the speed and the frequency of new product introductions at the corporate level, while the first has focused on the speed of individual projects as well as engineering resources utilized. These two types of new product development capabilities, speed in individual product-development projects and frequent new product introductions, are interrelated and yet different issues. But the combination of these two capabilities may provide firms with more opportunities to grow revenues by attracting new customers and meeting changing customer needs more easily than firms which have long development lead times and infrequent new-product introductions.

The concept of the multi-project strategy in this paper covers the gap between these two perspectives. A firm's capability to develop a single project alone is not necessarily sufficient for effective management of a stream of new products over time. Developing a successful stream of new products over many years and taking repeated advantage of designs and components in more than one product without overly compromising the design of the final products requires specific strategy, planning and coordination above the level of the individual project. Among academic researchers, little study has been made of the management of multiple new product development efforts across both multiple product lines and multiple generations of products from the perspective of the corporation as a whole.

In recent years, however, some researchers have started emphasizing the strategic importance of planning for and managing the evolution of a sequence of new products (Hayes, et al., 1988, Wheelwright and Sasser, 1989; Meyer and Utterback, 1993). Wheelwright and Sasser (1989) for example, have discussed the importance of the effective strategic management of a core product with a distinctive platform and its derivative projects. (Similar discussions are also seen in Hayes, et al., 1988, and Wheelwright and Clark, 1992). They have discussed this strategic issue by suggesting a framework known as the product generation map, and by applying it to product evolution patterns at two firms in the vacuum cleaner industry. Meyer and Utterback (1993) have also discussed the management of product families. They emphasized the importance of the planning and the managing the evolution of a portfolio of products, focusing on the development and the application of a firm's core technology. The concepts of managing the product generation map and the product family are related to this study. However, these researchers have not yet empirically examined the relationship between different strategies explained by these frameworks and performance in the marketplace.

2 Dimensions of Multi-Project Strategy

Effective management of a firm's special competencies or resources has been considered as one of the primary aspects of a firm's competitiveness (Wernerfelt, 1984; Prahalad and Hamel, 1990). With respect to new product development, examining the strategy for specific linkages among all projects within a firm is one way to understand the effective management of a firm's resources (Meyer and Utterback, 1993). Different ways multiple projects relate to each other technologically should have different impacts on a firm's performance in the market, as well as on the structure of their organizations. Consideration of multi-project strategy includes both the linkages between different product lines (inter-product line linkages) and the linkages between past and present projects (evolutionary linkages). The management of these linkages technically and organizationally is a strategic and potentially critical issue for the firm's effectiveness overall in product development.

One of the primary focuses in the existing literature on product strategy is the extent of technological newness. Many studies have discussed the distinction between radical innovation and incremental change (Ettlie, et al., 1984; Dewar and Dutton, 1986; Kleinschmidt and Cooper, 1991). There is also a body of literature that has focused on the effects of the relatedness or the newness of a project's technical requirements compared to a firm's existing competencies in technology and marketing (Johnson and Jones, 1957; Abernathy and Clark, 1985; Meyer and Roberts, 1986). This distinction has provided some useful insights regarding the effectiveness of product development strategy. 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 standing in an existing market (Hollander, 1965). Furthermore, new products based on technologies related to existing products often provide a firm with a better chance to grow in the market than products based on technologies unfamiliar to the firm (Meyer and Roberts, 1986).

This type of simple distinction -- whether a product's technology is new or related to existing products -- is useful but insufficient for researchers and managers to characterize and to understand the effectiveness of a firm's product strategy for an entire project portfolio over multiple generations and across multiple product lines.

This study focuses on two other perspectives that have been often underestimated with respect to different ways to utilize existing product technologies within the firm. First, technologies that are based on existing products with some modifications or enhancements can be used in a redesign of the same product line for a replacement, or in other cases they can also be transferred to another product line that targets a different market segment from the original product. While, in the first case, firms enhance the competitiveness of an original product, in the second case, they transfer technologies of one product to others to capture a new market segment and achieve economies of scope in development. These two different applications of the same "incremental change" scheme have clearly different implications on market competition at the corporate level. It is necessary to analyze the impact of the incremental changes by separating effects of the pure product enhancement verses the scope strategies.

Second, the timing of exploiting existing technologies should be another critical factor that affects a firm's competitiveness. Depending on whether the original technology that is modified and exploited is already obsolete or still relatively new, the same degree of modifications to existing technologies and designs within the firm should have a different impact on the competitiveness of new products in the market. It is a reasonable assumption that a technology that is originally competitive usually becomes less competitive as time passes. In particular, while there have been numerous studies focusing on the scope strategy (Teece, 1980; Goldhar and Jelinek, 1983; Clark, 1989), the timing when sharing activities or technologies actually occurred among multiple projects has been all but ignored.

GM and Chrysler illustrate the importance of these different perspectives. GM has not been trying to share the same platform (the basic framework of the automobile design) among different products and has not been taking advantage of all possible economies of scope in development (or manufacturing). It is now trying to reduce the number of platforms it builds and to leverage the same platform technologies and designs with some modifications among more product lines than before (Newsweek, November 1, 1993: PP, 126). On the other hand, Chrysler developed and introduced a new compact car line, the K-car, with a new platform technology and design in 1980. This product was competitive in the market and Chrysler leveraged the design for several new products throughout the 1980's. Although at first this strategy worked well and helped the firm increase its sales and profits, by the end of the 1980's new products based on the enhanced K-car platform had become old and declined markedly in sales. While the GM example suggests the usefulness of exploiting scope economies in new product development, the Chrysler example suggests that there are limits to this strategy. Firms do not need to introduce totally new technology with each new product, but they should introduce new technology more frequently than Chrysler did in the 1980s.

In addition to the implications on market competitiveness, these differences in technology sourcing and transfer timing may potentially require different types of corporate-wide organizational structures and processes, particularly for inter-project coordination. There could be a case, for example, where a new project tries to utilize a new technology from an ongoing project. While a new technology can be leveraged among multiple products most quickly in this way, there should be ongoing coordination between the projects. Thus, there may need to be different organizational structures and processes in place depending on whether technology transfer occurs between concurrent projects or from a past project to a current project. Japanese firms that introduce many different products frequently, for example, sometimes coordinate multiple ongoing projects to speed up their introduction of multiple products.

This study focuses on three dimensions of multi-project strategy: the extent of changes, sources of the base design, and the timing of design transfers. The paper first proposes a typology of multi-project strategies and discusses hypotheses regarding the relationship between different types of strategies and market growth performance. Second, using data on 210 new products introduced by 17 worldwide auto manufacturers between

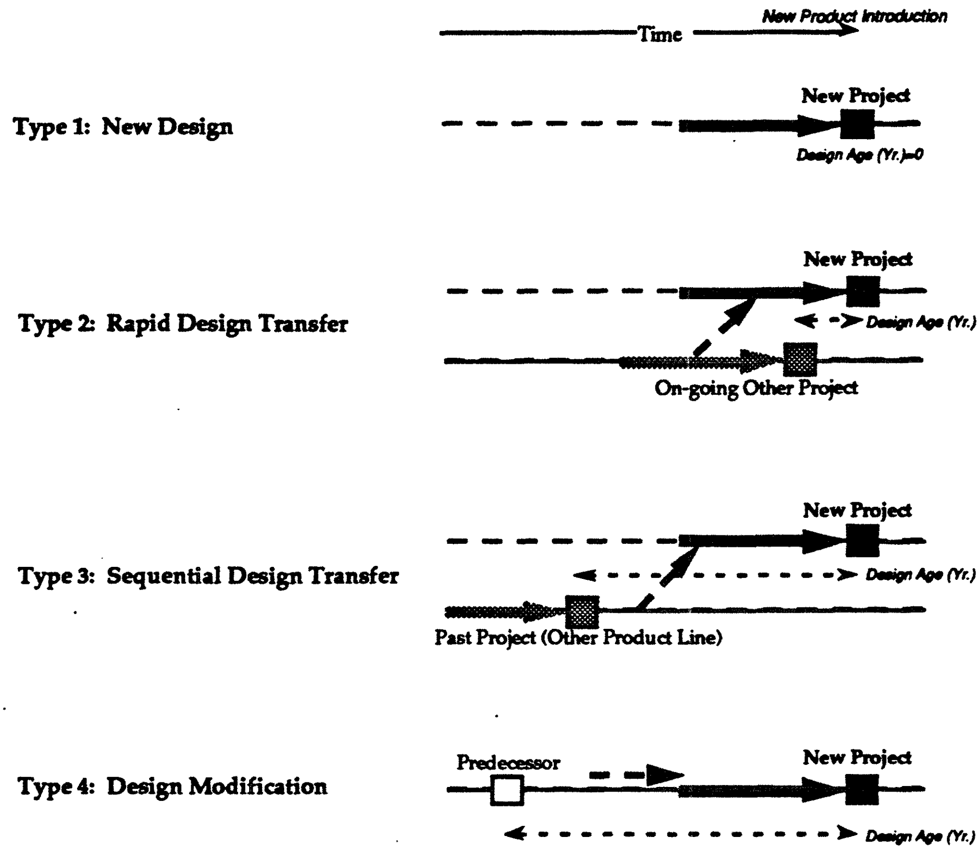
1980 and 1991, this paper argues that high performers (measured by market share growth) more often utilized one type of strategy: what we call a "rapid design transfer" strategy. Finally, we conclude by discussing implications and limitations of the study.

3 Framework: A Typology for Multi-Project Strategy

Firms have various alternatives for multi-project strategies used in new product development. In order to analyze complicated patterns of different multi-project strategies, Figure 1 proposes a multi-project strategy typology which focuses on inter-project linkages. This typology categorizes new product development projects into four types, depending on the extent of changes, sources of the base design, and the timing of design transfer. This typology covers all types of new product development projects, and these four types are mutually exclusive.

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

Figure 1 Typology of the Project Strategy on Inter-Project Linkages



Note: Design age is the age of the core design used by a new project, measured at the time when the new product is introduced.

The extent of change required in a new project determines whether its core design (e.g., platform design) is newly developed or transferred and modified from another project. New product projects that develop their platforms primarily from scratch without a preexisting base design are categorized as the first type, *new design strategy.* 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). In our framework, however, incremental changes are broken down into three types, depending on the location of the base design source and transfer timing: either an ongoing other project, an existing other product, or the new project's direct predecessor product. These three types are labeled here as *rapid design transfer*, *sequential design transfer*, and *design modification*, respectively. Thus, the typology has four multi-project strategy types, including the new design strategy and three variations of the enhanced design strategy.

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

The next two types of projects transfer and share a core design from other projects within the firm. In the second type, ***rapid design transfer***, a new project begins to transfer a core design from a base project before the base project has completed its design engineering (generally, within about two years of platform completion, as discussed further in the next section). These two projects -- the new project and the base project -- require extensive and potentially costly coordination because: (1) some of the development phases overlap chronologically; (2) the downstream project needs to incorporate a design from the base project while the design is still under development or relatively new; and (3) mutual adjustments in design between the two projects are possible and likely.

The third type, ***sequential design transfer***, transfers a design from a base model to a new model after the base model's development is finished. Because this type of project basically reuses an existing design that is "off-the-shelf," ongoing inter-project coordination is neither possible nor needed. When a new project uses the core design in this manner, however, the design being transferred is already relatively old compared to designs transferred while a base model is being developed, as in rapid design transfer. In addition, design constraints may be high in sequential design transfers because mutual adjustments between projects on the core design are no longer possible, forcing the new project to accommodate elements of the base core design from an older product. This type of transfer may not be efficient or effective, compared to rapid design transfer, because concurrent design-task sharing and mutual adjustments are not possible. This discussion of hypothetical differences between rapid and sequential design transfer is partially based on Thompson's distinction between "long-linked technology" and "intensive technology," where the latter also requires mutual adjustments and higher coordination costs (Thompson, 1967).

The last type, ***design modification***, refers to a new product project that develops a core design directly based on that of a predecessor product. This type of project does not need any inter-project coordination either, but has to consider constraints from the core design of the predecessor product (i.e., the current model). The difference between the design modification and the sequential design transfer is thus the source of the base design and its application. In this definition, the extent of modification from the base design does not have to be less than that of rapid design transfer or sequential design transfer. Design modifications may be easier than a sequential design transfer, which transfers a core design between different product lines. Another difference by definition is that sequential design transfer can be used to add a new product line, while a design modification is only for replacement projects.

One of the useful features of this typology is that it determines the design age of each strategy type, which is the age of the core design (i.e., platform) a new project uses. For example, the design age of a new product that uses a core design that was originally introduced to the market 10 years ago by the firm is 10 years. As shown in Figure 1, design age is determined for each multi-project strategy type by the difference in time between the introduction of the new product and the first introduction of the original design on which the product is based. The concept of the design age is central to any analysis of the timing of inter-project transfer strategy because it measures how quickly a new platform design is leveraged by its use in multiple projects within the firm.

For example, the design age of a new product utilizing a transfer strategy, either rapid design transfer or sequential design transfer, is the time that has passed since the base product, which was developed as an original new design, was introduced to the market. In other words, design age is a measurement that differentiates design transfer strategies, either rapid design transfer or sequential design transfer. The strategy is determined by how quickly the original new design is transferred from a base project to a new project. The design age of a new product using the design modification strategy is the same as the product life cycle of its predecessor model[1]. The basic concept of the design age for the design modification reflects the transfer strategy between two generations of products for the same product line. The design age of a new product that develops a core design from scratch using the new design strategy is zero.

4 Hypothesis: Impact on Market Performance

There are two critical company-level output dimensions that are closely related to the multi-project strategy: the new product introduction rate and the average core design age of new products a firm actually introduces to the market. The new product introduction rate is defined as a ratio of the number of new product introductions adjusted by the number of product offerings in a base year. The average core design age is the average of

[1] If a new product is itself a design modification of a second, earlier modification (or a string of modifications), the design age is found by going back to the most recent original design.

platform design ages of these new products for each firm. When we began this research, we hypothesized that firms that introduce more new products (higher new product introduction rate) with newer designs (lower average core design age) across these new products should gain more in market share. In addition, we believed that different multi-project strategies would affect both the new product introduction rate and the average platform design age.

A number of studies have provided evidence that frequent product introductions have a positive influence on market share growth. A higher new product introduction rate makes it possible for a firm to replace existing products with improved ones more quickly, or to broaden their product lines more quickly than competitors, if desired (Miller, 1988; Fujimoto and Sheriff, 1989; Kekre and Srinivasan, 1990). Broader product lines may enable a firm to 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).

In addition, the impact of the new product introduction rate on market performance may be particularly important in industries such as automobiles where two general conditions seem to hold[2]:

1) technology improves steadily in small increments, instead of through radical improvements only once a while, and marginal superiority is the basis for product competition in the marketplace; and

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

In order to increase the new product introduction rate, firms usually need to invest more financial and engineering resources. Otherwise, frequent new-product introductions may reflect incomplete development efforts and result in products that suffer from problems in design quality and perform poorly in the market (Crawford, 1992). If firms want to save on their resource investments and still maintain a high new product introduction rate, they may have to decrease new components in each project and carry over substantial portions of existing designs. A project that develops more new components generally requires more lead time and engineering resources (Clark and Fujimoto, 1991). Thus, it may not be a reasonable choice for a firm that pursues a high new product introduction rate to extensively utilize the new design strategy.

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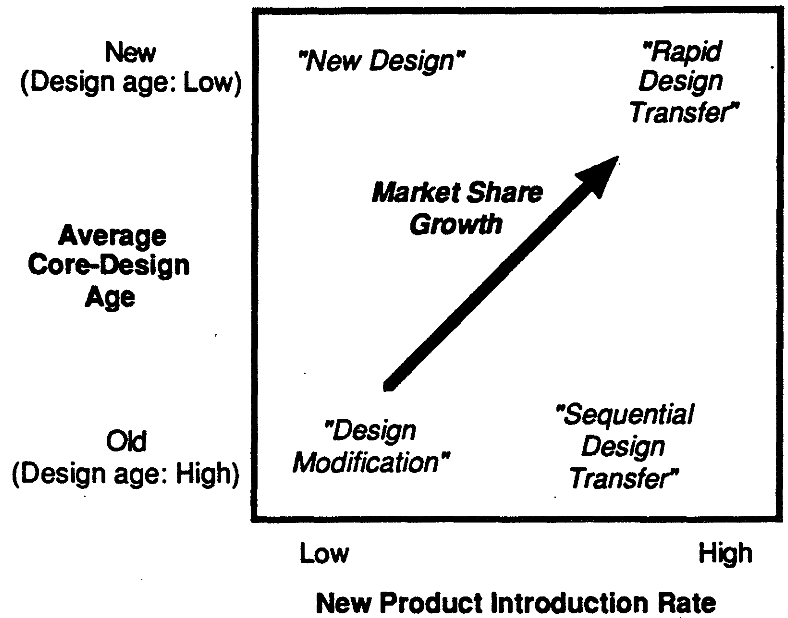
2 Fujimoto (1989) also discussed the world car market using a similar set of assumptions.

In other words, firms may want to use existing components repeatedly in multiple projects over time to make the most of their financial and engineering resources in new product development, similar to how factories assemble different products from standardized parts or modules. (Cusumano, 1991). However, if firms use old components too often, such repeated use of the same old designs may have a negative impact on market competitiveness. One of the purposes of frequent new product introductions is to meet changes in customer tastes and needs with new technologies and designs. The reuse of an old design may conflict with this objective. Reuse of an old core design as a base may also impose constraints on introducing new designs for other components. By contrast, the rapid reuse or transfer of new technologies and designs among multiple projects may actually improve the overall newness and technological sophistication of a firm's multiple product offerings. Therefore, the negative impact of design transfer on a firm's market competitiveness may depend to some extent on the average core design age of new products introduced into the marketplace and then used as the basis for design transfers.

One of the primary goals of new product developments at the corporate level is not only to introduce new component technologies and designs into a single product line, but to introduce them into a set of product lines targeting different market segments as quickly as possible. Firms may achieve this by developing new and unique designs for all of their individual product lines separately. Firms usually cannot do this consistently and quickly because of their limited engineering and financial resources. They instead use existing technologies from present and past projects. Firms can best utilize new technologies and designs across multiple projects by quickly transferring them while these technologies and designs are still fresh. The measurement of average core design age captures both the rate of new core design development and the speed in transferring the new core designs across multiple projects. Although in recent years the speed to market of a single new product development has been extensively studied, a critical benchmark that has rarely been explored either conceptually or empirically is "speed in technology leverage". Speed of technology leverage is related to the speed of new product development at the corporate level.

Automobile firms successful in market share growth should develop more new products without relying on older designs than their competitors. One of Clark's findings, for example, implied that, in order to avoid a tradeoff between new designs and reused designs, some of the successful Japanese manufacturers depended more on outside suppliers for new components (Clark, 1989). Our study explores the idea that successful manufacturers may also have multi-project strategies that differ from those of low performing manufacturers in order to mitigate this tradeoff. We can summarize our arguments from the discussion above in two hypotheses regarding the relationship among different multi-project strategy types, average core design age, new product introduction rate, and market share growth performance, as exhibited in Figure 2.

Figure 2 Hypotheses on Inter-project Types

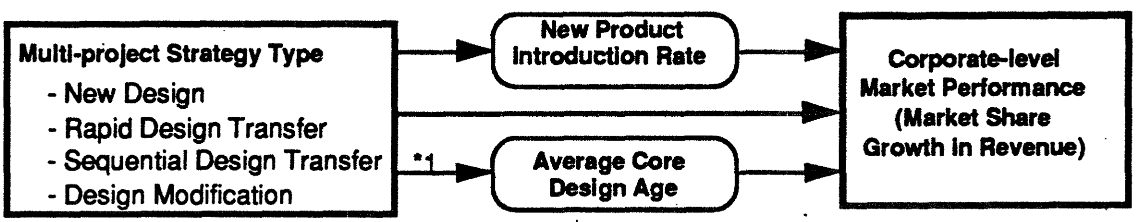


First, firms that develop more new products than their competitors (i.e., have a higher new product introduction rate) without reintroducing older designs (i.e., have a low average core design age) should increase market share. Second, in order both to increase the new product introduction rate and maintain a low average core design age of the new projects, a firm should extensively choose to follow the rapid design transfer strategy. This allows a quick design transfer among multiple projects while a design is still relatively new. An extensive usage of the rapid design transfer or sequential design transfer strategies may provide firms with a greater advantage in developing more new products than the other two multi-project strategy types by sharing designs among multiple projects. However, it should be recognized that a new product using sequential design transfer results in the incorporation of older technologies into the product than those products using rapid design transfer.

On the other hand, extensive use of the new design strategy may result in a low average core design age but may have a negative impact on the new product introduction rate. In this case, firms may tend to focus their financial and engineering resources on a limited number of new products, without reusing existing designs or sharing the same components across multiple projects. This strategy may be effective in preserving the market competitiveness of an individual product line, but do little to help a firm improve or expand its product portfolio. Finally, focusing on design modification is not advantageous either in terms of the new product introduction rate or the average core design age. Under this strategy, an existing design may be enhanced relatively slowly over multiple generations of the same product, and it is not leveraged among multiple product lines. When only an individual project for a product line is considered, the design modification strategy seems to be effective. However, in the framework of the multi-project strategy, we hypothesized that this strategy would be the least effective at least for predicting a firm's growth rate in sales.

The model in Figure 3 summarizes these hypotheses, which we use in regression analyses of the relationships among these four constructs.

Figure 3 Analytical Model



*1: This relationship is mostly determined by the definition of the multi-project strategy type and the core design age as shown in Figure 1. Therefore, these two variables are not analyzed in the same regression models.

5 Sample Characteristics and Measurements

The sample in this study covers the 17 largest passenger car manufacturers in the world, including five Japanese (Toyota, Nissan, Honda, Mazda, Mitsubishi), three U.S.. (GM, Ford, Chrysler), and nine European producers (VAG, Mercedes-Benz, BMW, Opel, Ford of Europe, PSA, Renault, Fiat Group, Volvo)[3]. These firms introduced, in total, 210 new car products to the international market, including the U.S., Europe, and Japan, between 1980 and 1991, according to our definition of distinctive new products (explained later in this section). Data on new product development in the industry were primarily collected from *Automobil Revue*, an annually published Swiss industry journal that covers introduction

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

dates and design features in detail for all new car products worldwide[4]. Interviews with approximately 130 engineers and 30 project managers in these firms worldwide were also conducted to develop our analytical framework.

Data were divided into four three-year time periods: 1980-1982, 1983-1985, 1986-1988, and 1989-1991. The combination of 17 firms and four time periods makes 68 combinations. Among the 68 combinations, three are not used because three firms introduced no new products during one of the four time periods. These resulted in a total of 65 data points describing company-level strategies[5].

New Product Introduction Rate and Definition of a New Product

The new product introduction rate was calculated for each manufacturer during each of the three-year periods by the ratio of the number of new product introductions divided by the number of product offerings in the base year. For example, this ratio is the same for two firms when one firm that originally has six product offerings develops three new products during a certain period, and the other firm that originally has four product offerings develops two new products; in either case, the new product introduction rate is 0.5. Our data cover all primary markets in the world, including North America, Europe, and Japan, and include all major new car products introduced into any of these markets with the exceptions of "special off-line" and "externally-developed" cars[6].

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 face-lift or a variation that consists

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4 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.

5 We chose the scheme of four three-year periods because we believe that a longer interval such as two six-year periods may create a causality problem since a six-year period would allow firms to choose a product strategy directly reflecting their market performance within the same period. A longer period scheme may also weaken the impact of distinctive strategies, because aggregate performance data are used in this study. A shorter period such as two years is too short to capture a dynamic multi-project strategy and is not conceptually appropriate for this research framework. For example, many firms did not introduce any new products or introduced only one product even during the 3-year periods. Therefore, we conducted a sensitivity test using two additional division schemes, including three 4-year periods and two 6-year periods. We also conducted sensitivity tests using data points without any one of the four 3-year periods. Results from these sensitivity tests provided us with similar results to this division scheme, which we will discuss later.

6 In this research, we do not count "special off-line" products such as the Toyota Sera, the Dodge Viper, the Honda NSX, the Nissan PAO, or the BMW Z1, whose production volume is approximately 0.5% or less of a firm's total car production volume, because these products are not often developed with the same level of production preparation or development standards as other mass-production models. In addition, these models often target symbolic effects such as a firm's image rather than sales income. 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.

of minor cosmetic modifications[7]. Additional body and styling types for existing car models are not counted as new products either. 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 multi-brand project like the General Motors GM10 project (Pontiac Grand Prix, Oldsmobile Supreme, Buick Regal and Chevrolet Lumina) are counted as only one new product[8].

This analysis focuses on the management of multi-project strategy and inter-project organizational interactions at the platform level, rather than the management of the development of minor variations such as multiple body types or styling variations for different sales channels. Therefore, whether two or more new variations were in fact developed together within one project or separate projects is critical to this study. For example, this affects the total number of new projects and the nature of their interrelationships. Most new car products, such as the Taurus and the Sable, are openly discussed in industry journals and car magazines mentioned earlier.

Average Platform (Core) Design Age

The platform design age is zero for new product projects that develop new platform designs without any preceding base design as defined in Figure 1. Again we characterize this as a new design strategy under our typology scheme. The platform design age for projects that develop new products based on platforms from other projects or their direct predecessors is measured by the difference in time between the introduction of the new product and when the base product was first developed. The average platform design age is an average of all new products a firm introduced during each three year period between 1980 and 1991.

Multi-project Strategy Types

In order to determine whether the platform of a certain new project was newly developed or transferred from a preceding product, we assigned points to the extent of changes in platform design between the new product and preceding products similar to the

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7 Major components for exterior styling include doors, fenders, pillars, a roof, bumpers, a windshield, a hood, a trunk lid, a hatchback door, a front grill, and exterior moldings. A new exterior styling means that all of these components are new. The same method is also applied to the change 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 "face-lift product." For example, in Japan, industry people (and customers) clearly distinguish these two by referring to these as a "major-change" project and "minor-change" project, respectively.

8 Some other examples are the Camaro and the Firebird variations developed under GM's 1981 F-car project, which are counted as one new product. At Toyota, variations developed by a single project, the 1989 Celica project, include the Celica, the Carina ED, and the Corona Exiv, and are counted as one new product.

new product, based primarily on changes in the wheelbase and track as well as the suspension design. These measurements cover the extent of changes in platform design that consist of floor panels, under-body structure, and the suspension design (see Appendix 1 for the point scheme).

New product projects that newly develop platform designs without any preceding base design are categorized as following a new design strategy. In many cases, it was easy to identify new designs because firms often adopted new technologies for platform designs during this period (1980-1991). Some new products were changed from rear-wheel-drive to front-wheel-drive, and others introduced new suspension technologies such as multi-link or compact double wishbone systems. (See Appendix 1 for descriptions of major new suspension systems during this period.) To incorporate such major changes, completely new platform designs are required.

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

We categorized new projects as rapid design transfers when the transfer from a base project occurred within 2.0 years of the introduction of the base design. We did this for several reasons. Our interviews with engineers revealed that if the time lag is longer than approximately two years, then there usually is not much overlap or coordination between a base product project and a new product project, because the former is usually completed before the latter begins. In our definition, a key factor that conceptually differentiates rapid design transfer from sequential design transfer is whether overlap in platform design exists between the new project and the base project. This two-year cutoff point is also supported by the results from another part of this research project that used a questionnaire survey of project managers with respect to different inter-project platform strategies in new product development projects (See Nobeoka, 1993). According to our separate survey data, platform design transfer between multiple projects within 2.0 years is always associated with interactions between a base project and a new project. Those projects whose transfer lag is between 2.0 years and 3.0 years show mixed results; some projects have interactions with a base project and some do not. All projects that are delayed from a base project by 3.0 years or longer do not have any interactions with the base project. The figure 2.0 years is also reasonable because it is close to the midway point (2.25 years) for the average lead time for new car development (4.52 years) as calculated by Clark and Fujimoto (1991: 73). Nevertheless, we also tested the sensitivity of the 2.0-year division by using 1.5 years and 2.5 years as cutoff points, and discuss these results later.

Usage of Different Multi-project Strategies (%)

We measured usage of different multi-project strategies by determining the percentage of each multi-project strategy type out of all new car products introduced by a firm during a three-year period. For, example, if a firm introduces ten new products during a three-year period and three new products are categorized as rapid design transfers, usage of the rapid design transfer strategy during this period is calculated as 0.30. As this example implies, usage of different multi-project strategies is particularly meaningful when it is analyzed in conjunction with the new product introduction rate. In our analyses, both variables are generally considered together.

Market Share Change

Market share was calculated using estimates of revenues for each product in North America, Japan, and Europe. This revenue was calculated 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. The average sales prices we used were those in the U.S. market, adjusted to 1991 prices[9]. For products not available for purchase in the U.S. market, prices were estimated by their equivalent products in the U.S. market with respect to size and equipment level. Market share change is the percentage change in a company's share of total industry revenues from the beginning of one three-year period to the end of the same period.

9 This methodology is similar to using purchasing power parity rather than exchange rates, and minimizes the impact of changing exchange rates on the market-share data. This is particularly important for the Japanese firms, since the ratio of the yen has increased dramatically during the time periods studied.

Table 1 Summary of Performance and Strategy Variables

New Product Introduction Rate	- # of new products during a 3-year period, divided by # of product offerings in the beginning of the first year of the period. - A new product includes all model variations developed within a single project. - A new product has new interior and exterior stylings. Additional variation projects such as new body types or stylings are not counted as new products. - "Special off-line" products are not counted as new products.
Average Platform Design Age (years)	- An average of platform design ages for all new products introduced during a 3-year period. The platform design age is defined as time passed since a platform each new product uses was originally developed and introduced (see Figure 1).
Usage of Multi-project strategies (in percentage)	- # of new products using each multi-project strategy during a 3-year period, divided by the total number of new products introduced during the 3-year period.
Multi-project strategy	
New Design	New products that develop a new platform.
Rapid Design Transfer	New products that use a platform a project for a separate product line originally developed. Transfer occurs within 2 years of the introduction of the product that originally develops the platform.
Sequential Design Transfer	New products that use a platform a project for a separate product line originally developed. Transfer occurs at least 2 years after the introduction of the base product.
Design Modification	New products that use a platform a predecessor (an earlier generation) of the same product line originally developed.
Market Share Change (percentage)	Percentage change in market share (revenue in $) from the beginning of each three-year period to the end of the period.

Examples of Different Multi-project strategies

The following examples illustrate how we categorized different products from various manufacturers according to the four multi-project strategies.

(1) Design Modification

In 1987, Toyota and Honda introduced the new Corolla and the new Civic, respectively. The typology scheme in this study categorizes the 1987 Corolla as a project that followed the design modification strategy and the 1987 Civic as a new design strategy. Product variations of the Corolla include the Corolla (4-door sedan), the FX (3-door hatchback), the Levin (3-door coupe), the Sprinter (4-door sedan), the Cielo (5-door hatchback), and the Trueno (3-door coupe). Among them, there are four completely separate exterior stylings, and two completely separate interior stylings. Other variations share some of the styling components. Because these exterior body stylings and interior stylings are completely different from any of the previous Corolla series, our scheme counts this Corolla series as a new product. Despite these extensive variations, the definition of a distinctive product discussed earlier counts all the Corolla product variations as one product because all were developed within the new Corolla project. With respect to the platform design, Automobil Revue (1989) describes the chassis 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. "(p. 554)*

The suspension system in the previous Corolla, the 1983 Corolla, is described in Automobil Revue (1987), and is identical to this description for the new 1987 Corolla. Car Styling (1987, volume 59, p. 59) also explains that "*as before, the suspension is by L-shape lower arms and McPherson strut at the front, with parallel arm struts at the rear. Lateral rigidity at the front has been increased by moving the front pivot 40 mm forward...* " Therefore, the change in suspension of the new Corolla from that of its previous model is categorized as "suspension system is the same, but the design is modified" according to the criteria described in the Appendix 1. With respect to the change in floor panels, using the categorization scheme in this study as explained in the Appendix, we referred to the wheelbase and track dimensions of both the 1983 Corolla and the new Corolla. The wheelbase and the front track for both products 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, the new Corolla project is categorized as a design-modification project. In order to determine the platform design age of the new Corolla, we had to find out when the platform was originally developed. Using the same method as discussed above, we found that the platform was actually newly developed for the 1983 Corolla. Therefore, we were able to determine that the platform design age of the 1987 Corolla was 4.0 years in May 1987 when it was introduced.

(2) New Design

The new 1987 Civic project developed product variations including the Civic (3-door hatchback and 4-door sedan), the CR-X (3-door coupe), and the Shuttle (5-door hatchback). This project also has wide variations, which include three completely different body stylings and three different wheelbases. All of these variations are counted as one product because all of them were developed by a single project team. If one of the variations, such as the CR-X, had been developed as a separate project, we would have categorized it as a rapid design transfer project. An article in Car Styling (Volume 61, 11/1987, p. 78) confirmed our categorization and notes that the Civic, the CR-X, and the Shuttle were all developed within the same project led by project manager Hiroh Watanabe.

With respect to the suspension systems and the chassis of the previous Civic, the 1983 Civic, and the 1987 Civic, Automobil Revue (1984 and 1989) explains 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, p. 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, p. 313)*

The suspension system in the new Civic is a variation of four-wheel double-wishbone types, and that in the old Civic is 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 new system compared to either the 1983 Civic or any other existing designs at that time in Honda. This platform was also technically innovative because no other products of this size had a double-wishbone type suspension. The wheelbase/track for the new Civic 4-door sedan and the old Civic 4-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, the new Civic is categorized as a new product under the new design strategy. Its platform design age is zero, as defined earlier.

(3) Rapid Design Transfer

In May 1988 Honda introduced a new product line, the Concerto. Thirteen months earlier, the 1987 Civic, as discussed above, was developed as a completely new platform, utilizing a variation of the four-wheel double-wishbone suspension. The Concerto project and the Civic project were organizationally separate and were managed by different project managers. The Concerto project developed two different body types (4-door sedan and 5-door hatchback). Exterior and interior stylings of the Concerto are completely different from any variations of the 1987 Civic. However, the suspension system of the Concerto is identical to the one in the Civic described above (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 and stretched the wheelbase by 50 mm, which may have required a modification to one of the Civic's floor panels. Because the Concerto was introduced only 13 months after the Civic project, we categorized the Concerto project as following the rapid design transfer strategy.

300ZX as a replacement for an existing sports car, the 280ZX. The 300ZX employed a novel platform with a completely new four-wheel multi-link suspension system, which Automobil Revue (1989) describes as follows:

> *"Integral body; all round multiple arm independent suspension with coil springs and co-axial telescopic damper, front lower control arm with tension strut, top semi-trailing arm, articulating arm, rear lower A-arm, axial strut, lower single control arm and diagonal struts, antiroll bar front and rear"(p. 437).*

The 300ZX project is an example of a new product following the new design strategy. Nissan introduced the new Skyline in March 1989, which included both a 4-door sedan and a 2-door coupe. The Skyline and the 300ZX were developed by two separate projects: the Skyline was developed by a project led by project manager Shinichiro Sakurai (Car Styling, July 1989, vol. 71, p. 38), and the 300ZX was developed by a project led by project manager Katsuo Yamada (NAVI, October 1989, p. 17). Though separate projects, the Skyline employed the exact same chassis specifications as that of the 300ZX. The Skyline project transferred the platform from the 300ZX with the time lag of only three months. Therefore, the Skyline project was categorized as a rapid design transfer.

By comparison, in February 1983, GM introduced a replacement for the Chevrolet Corvette, a sports car, with a completely new platform employing an innovative four-wheel double-wishbone suspension system, which is described in Automobil Revue (1984):

> *"Integral body frame with front and rear axle support, all round independent suspension, front upper A-arm, trailing arm, control arm and steering tie rod; front and rear fiber glass leaf spring, anti-roll bar and telescopic damper" (p.. 134).*

This is again an example of a new design, similar to the Nissan 300ZX. However, this novel platform has never been seen in any other projects at GM since the introduction of the new Corvette. In other words, at GM, there has been neither a rapid design transfer nor a sequential design transfer project based on the latest generation Corvette.

(4) Sequential Design Transfer

Toyota introduced the new Tercel in September 1990. The project team developed the Tercel (2-door, 3-door, and 4-door), the Corsa (3-door and 4-door), the Corolla II (3-door), the Paseo (2-door coupe), and the Cynos (2-door coupe). There are many variations, but all came out a single project led by project manager Takashi Ishidera (Car Styling, 1991.3, vol. 81, p. 74). This project seems to have utilized a platform that was originally developed for the 1984 Starlet project, which was introduced to the market in August 1984. The suspension system of the 1984 Starlet is described in Automobil Revue (1986) as follows:

> *"Integral body; front McPherson struts and A-arm, rear compound axle (trailing arm, torsion tube) with coil springs, co-axial dampers and Panhard Rod, some models front antiroll bar" (p. 534).*

The 1990 Tercel has the same suspension specifications as the 1984 Starlet (Automobil Revue 1991). The 1990 Tercel's wheelbase is 80 mm longer than that of the 1984 Starlet, while tracks are the same between these two products. Therefore, we concluded that the Tercel used the platform design that was originally developed in 1984 for the Starlet project. The platform design age of the Tercel was already 71 months or 5.92 years old when the new Tercel was introduced. The 1990 Tercel is categorized as a product that followed the sequential design transfer strategy.

Other typical examples of sequential design transfers are found in new products at Chrysler. In September 1980, the Chrysler K-car project developed and introduced a completely new platform for the front-drive Dodge Aries and the Plymouth Reliant. The chassis of this platform is described in Automobil Revue (1982) as:

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

Chrysler used this platform with its relatively old suspension system as a base for several other distinctive projects, which include the 1983 E-car project (the Chrysler New Yorker and the Dodge 400), the 1984 G-car project (the Chrysler Laser and the Dodge Daytona), 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).

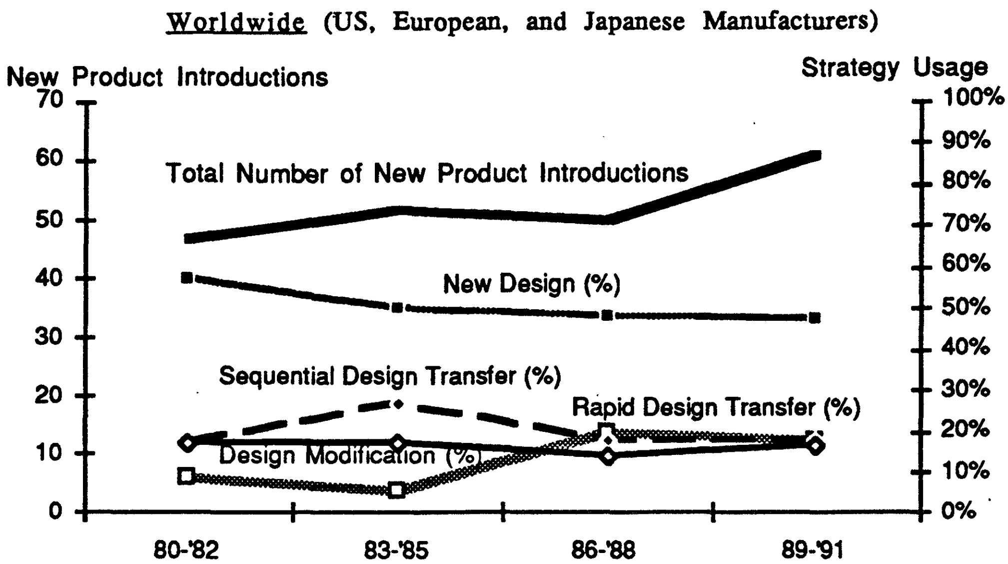
For example, the Dodge Shadow and Plymouth Sundance, which were introduced in March 1986, employed exactly the same chassis specifications and the same front track, 1460mm, as the original K-cars, the Dodge Aries and the Plymouth Reliant (Automobil Revue, 1987, p. 462). Because the wheelbase of the Shadow/Sundance is 75mm shorter at 2465mm than the K-cars, we concluded that the platform of the Shadow and the Sundance is a shortened version of the K-car platform. The platform design age of the Dodge Shadow and the Plymouth Sundance at the introduction date was already 5.5 years (the time difference between September 1980 and March 1986).

In this section, we explained our standard procedure for categorizing products primarily using specifications in Automobil Revue. However, most of the other industry journals, such as Automotive News and popular press car magazines, also discuss whether a new product is based on an existing old platform or not, what the base platform is, and how the new product has modified it.

6 Results and Discussion

Before we explain our analysis of the data, Figure 4 shows the trend of the total number of new product introductions (the thick line refers to the left scale) and the percentage of each multi-project strategy type. The graph shows the trend of new product development at 17 firms: three U.S., nine European, and five Japanese combined, during four three-year periods between 1980 and 1991.

Figure 4 Trend: Usage of Different Multi-project strategy Types



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. This trend implies that in the automobile industry, the speed of new product development has been accelerating during this period. In other words, both short lead times for individual projects and the corporate-wide frequency of new product introductions seem to have become even more important competitive factors than in previous years.

Changes are most evident in the speed with which designs are leveraged. Firms have been transferring new platform designs more quickly to other product lines throughout the period. This trend also implies that the management of overlap among multiple projects as opposed to single project management has become more important. Because the platform is a core sub-system, the management of its transfer cannot be done solely within a platform engineering group. The percentage of rapid design transfer, about 20%, means that almost 40% of projects needed to be coordinated at least to some extent, because each rapid transfer involves overlap with at least one other project from which the platform design is transferred.

Figures 5 and 6 illustrate the relationships we found between market share growth in sales revenue, the new product introduction rate and the average platform design age for the 65 data points, each representing the product strategy of one firm during a 3-year period. Analysis of the data in Figure 5 indicates that new product introduction rate and market share growth are positively correlated. Analysis of the data in Figure 6 shows that average platform design age and market share growth are negatively correlated. As our hypothesis suggested, these two plots support that firms that introduced more products with newer platform designs across the entire range of new products tend to have gained market share.

Figure 5 Market Share Change and New Product Introduction Rate

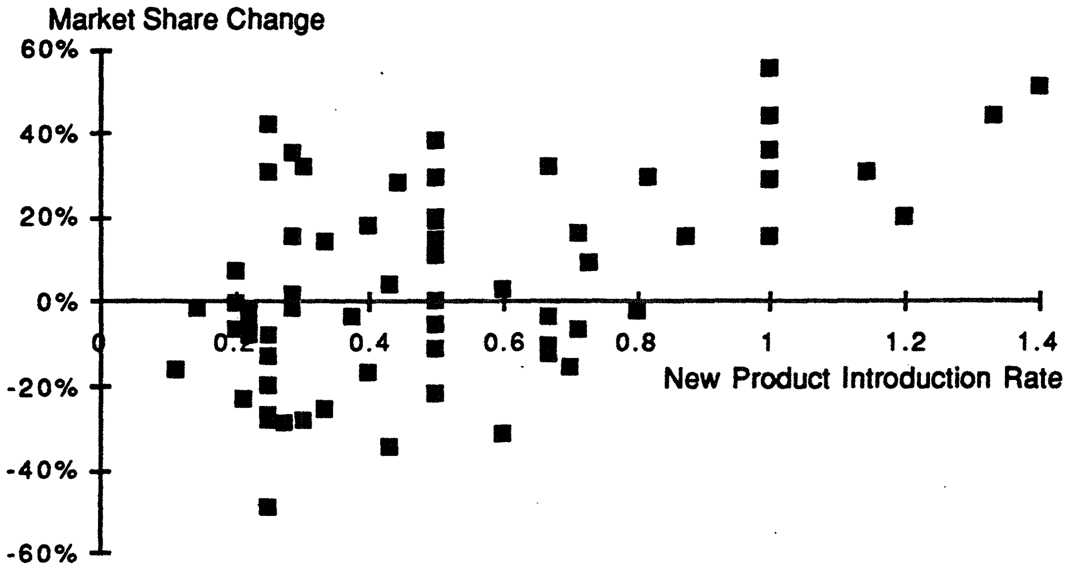
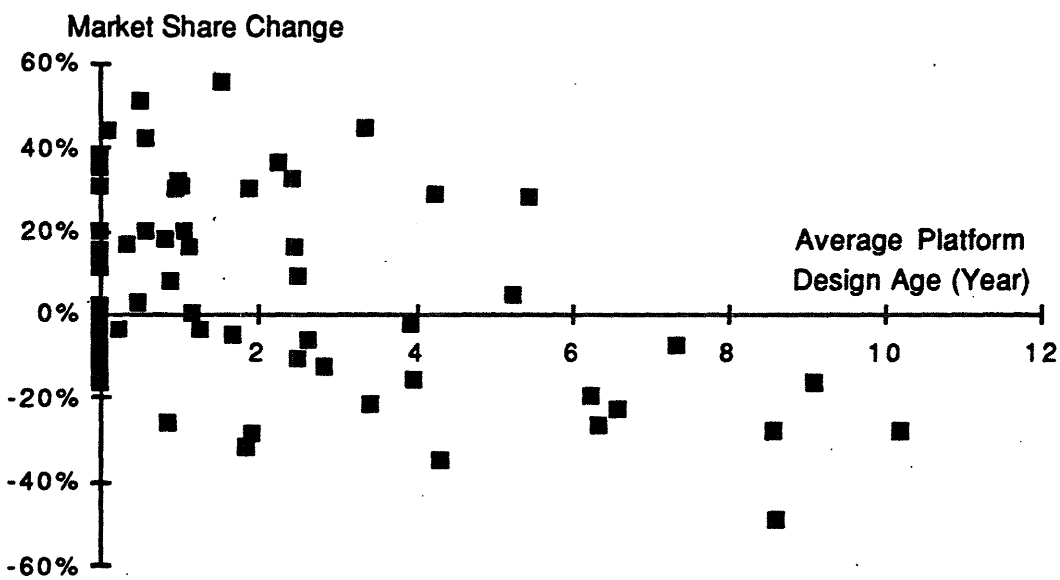


Figure 6 Market Share Change and Average Platform Design Age



Descriptive data and a correlation matrix for major variables are shown in Table 2. The average of changes in market share across all manufacturers is not zero (=0.05), because it is a percentage change in market share at each firm, which is itself a percentage. The new product introduction rate, on average, is 0.52. This number means, for example, if a firm focuses only on replacing existing products with new products, it replaces about half of all its car product lines during the three-year period. The average platform design age of new products is 2.10 years. A simplified explanation of this number is that a hypothetical firm develops two new products during a three-year period, and among them one is a new design (design age =0), and the other is a design modification based on a platform of a four-year-old existing product (design age =4.0). In this example, the average platform design age is 2.0 years old.

Table 2 Descriptive Data and Correlation Matrix (N=65)

			Correlations					
	Ave.	S.D.	1	2	3	4	5	6
1. Change in Market Share ($)	0.05	0.24	-					
2. New Product Introduction Rate	0.52	0.31	0.53 ***	-				
3. Average Platform Design Age	2.10	2.64	-0.45 ***	-0.17	-			
Usage of Multi-project Strategy (%)								
4. New Design	56.3	35.4	0.12	-0.08	-0.76 ***	-		
5. Rapid Design Transfer	10.0	18.0	0.41 ***	0.23 *	-0.25 **	-0.18	-	
6. Sequential Design Transfer	19.1	29.4	-0.08	-0.01	0.45 ***	-0.65 ***	-0.25 **	-
7. Design Modification	14.7	24.6	-0.38 ***	-0.05	0.73 ***	-0.54 ***	-0.17	-0.09

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

Both the new product introduction rate and the average platform design age have a strong correlation with market share change. On the other hand, the new product introduction rate and average platform design age are not significantly correlated with each other in either direction, positive or negative. These two variables seem to independently affect market share change, which is important and is to be more clearly examined in the regression analyses of Table 3. Correlation's between market share growth and the use of each of the different multi-project strategies indicate that only an extensive use of rapid design transfer has a strong positive correlation with market share growth, while an extensive use of design modification has a negative correlation.

Only an extensive use of new design or rapid design transfer strategies has a significant negative correlation with average platform design age (= positive correlation with a "newer" platform design). On the other hand, the other two strategies, sequential design transfer and design modification, are significantly correlated with a high average platform design age. With respect to the difference in the average platform design age, the results are not actually "findings," but directly reflect our definition of different multi-project strategies. With respect to the other important variable, the new product introduction rate, only an extensive usage of rapid design transfer has a significant positive correlation with it. In other words, only the usage of a rapid design transfer strategy is strongly associated with both a high new product introduction rate and a low average platform design age, as the framework in Figure 2 suggests.

Table 3 further analyzes these relationships in regression models with control variables including firm size, nationality of firms, and four different time periods. Firm size is measured by the number of product offerings throughout world markets for each firm at the beginning of each period. Among these control variables, different time periods and nationalities of the firms are particularly important for these models, because it is essential to adjust for the different economic and market conditions that firms in various regions may have faced during each of the four different periods. For example, the fluctuations in currency exchange rates throughout the four time periods may have caused different influences for firms in different regions.

Table 3 Regression Results for Market Share ($) Growth

Independent variables	Model 1	Model 2	Model 3	Model 4
Constant	0.00	0.00	0.00	0.00
New Product Introduction Rate		0.55 ***		0.48 ***
Average Platform Design Age		-0.29 **		
Multi-project Strategy (% of New Products)				
New Design			-	-
Rapid Design Transfer			0.35 ***	0.32 ***
Sequential Design Transfer			0.11	0.04
Design Modification			-0.25 **	-0.23 **
Market Coverage (# of Product Offerings)	-0.21	0.02	-0.13	0.00
Δ Market share ($) in previous period	-0.27 **	-0.18 *	-0.27 **	-0.23 **
Period (Dummy)				
80 - 82	0.06	0.05	0.17	0.18
83 - 85	-0.15	-0.14	-0.01	0.00
86 - 88	0.05	0.03	-0.01	0.04
89 - 91	-	-	-	-
Region (Dummy)				
US	-0.19	-0.16	-0.21 *	-0.23 **
Japan	0.31 **	-0.12	0.25 **	-0.11
Europe	-	-	-	-
Adjusted Squared Multiple R	0.22	0.42	0.39	0.49
Sample Size	65	65	65	65

Coefficients are standardized.
Statistically Significant at: * 10% Level, ** 5% Level, *** 1% Level

Market share growth of the previous period is also in the regression models to control for a firm-specific influence of the performance in a previous period on market performance. For example, those firms which perform extremely poorly in a previous period may tend to rebound toward better performance in the next period.

Model 1 only contains the control variables without any multi-project strategy variables. Japanese firms, in general, gained more market share than firms in either Europe or the U.S. Model 2 adds the new product introduction rate and average platform design age. As our hypothesis suggests, both the new product introduction rate and the average platform design age of new products significantly predict differences in market share growth even after controlling for other relevant factors. The influence of firm nationalities is no longer significant in Model 2.

In Model 3, the extent of usage of different multi-project strategies is included as an independent variable. Model 4 has both the new product introduction rate and the multi-project strategy variables[10]. In these models, an extensive use of the rapid design transfer strategy has a strong positive influence on market share growth. The rapid design transfer strategy enables firms to achieve both a high new product introduction rate and a low average platform design age, as indicated in Table 2 and as suggested by our definition of the categorization scheme, by quickly transferring new designs across multiple projects. Even though an extensive usage of the new design strategy reduces the average platform design age, using this strategy alone does not leverage the new designs across multiple product lines. A high percentage of design modification strategies has a negative impact on market share growth as our hypothesis in Figure 2 suggests.

We conducted various tests to examine the sensitivity of our data and analysis schemes (See Nobeoka, 1993 for specific results). First, we tested the potential influence of firm-specific factors, in addition to those analyses that consider only regional differences. Second, we conducted sensitivity tests for different data processing schemes, using two other alternative methods for period divisions: three 4-year periods and two 6-year periods. Third, we tested two other alternative cut-off points between 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.

Strategic Groups for Multi-project strategy

This section analyzes the same data using a different method to show the results more clearly. Table 4 categorizes the 65 data points into four different strategic groups depending on which multi-project strategy a firm used extensively during a 3-year period. In order to statistically categorize these data, we formulated strategic groups using the K-means cluster analysis[11]. Using all four variables that characterize the extent of usage of different multi-project strategy (%) in the cluster analysis, we categorized the data points into four groups. The strategies of firms in Groups 1, 2, 3, and 4 can be labeled as "new design-oriented", "rapid design transfer-oriented", "sequential design transfer-oriented", and "design modification-oriented," respectively. Data points in Groups 1, 2, 3, and 4 used new design strategy, rapid design strategy, sequential design transfer strategy, and design modification strategy, respectively, much more extensively than those in any other strategic groups.

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[10] Average platform design age is not in these regression models because it is, partially by definition, strongly correlated with the usage of different inter-project strategies.

[11] K-means cluster analysis "begins by picking 'seed' cases, one for each cluster, which are spread apart from the center of all the cases as much as possible. Then it assigns all cases to the nearest seed. Next, it attempts to reassign all cases to the nearest seed. Then it attempts to reassign each case to a different cluster in order to reduce the within groups sum of squares. Kmeans analysis continues to reassign cases until the within-group sum of squares can no longer be reduced." (SYSTAT: Statistics, 1992, 25) See Hartigan and Wong (1979) for the underlying algorithm.

Table 4 Performance Comparison among Strategic Groups

Strategic Groups	Group 1	Group 2	Group 3	Group 4
	New Design-Oriented	Rapid Design Transfer-Oriented	Sequential Design Transfer-Oriented	Design Modification-Oriented
# of Observations	26	15	11	13
# of Data Points by Region				
• Japan	6	9	0	5
• U.S.	4	1	3	4
• Europe	16	5	8	4
% of Multi-project Strategy Usage				
• New Design	92.0	46.0	22.6	25.2
• Rapid Design Transfer	0.6	41.0	0.0	1.0
• Sequential Design Transfer	4.4	5.8	72.1	19.1
• Design Modification	3.0	7.3	5.3	54.7
New Product Introduction Rate	0.45	0.69	0.51	0.47
Average Design Age***	0.37	0.91	3.75	5.54
Δ Market Share (%)***	3.4	23.4	9.1	-15.6

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

Summary Statistics for the K-means Cluster Analysis

Variable	Between SS	DF	Within SS	DF	F-Ratio	Prob.
Usage of						
New Design	47.7	3	16.3	61	59.7	0.000
Rapid Design Transfer	58.4	3	5.6	61	210.8	0.000
Sequential Design Trans.	45.3	3	18.7	61	49.4	0.000
Design Modification	43.2	3	20.8	61	42.3	0.000

Firms in Group 2, which used the rapid design transfer strategy most extensively among the four strategic groups, also used the new design strategy in 46% of their new products during the 3-year period. They developed more new products with relatively new average platform designs, and gained the largest market share, approximately 23% during the 3-year period compared to the last year of the previous 3-year period. The new product introduction rate for these firms averages 0.69 and is higher than that shown by any other strategic group. The average platform design age of new products that these Group 2 firms introduced during a three year period is 0.91 years, which is older than that of firms in

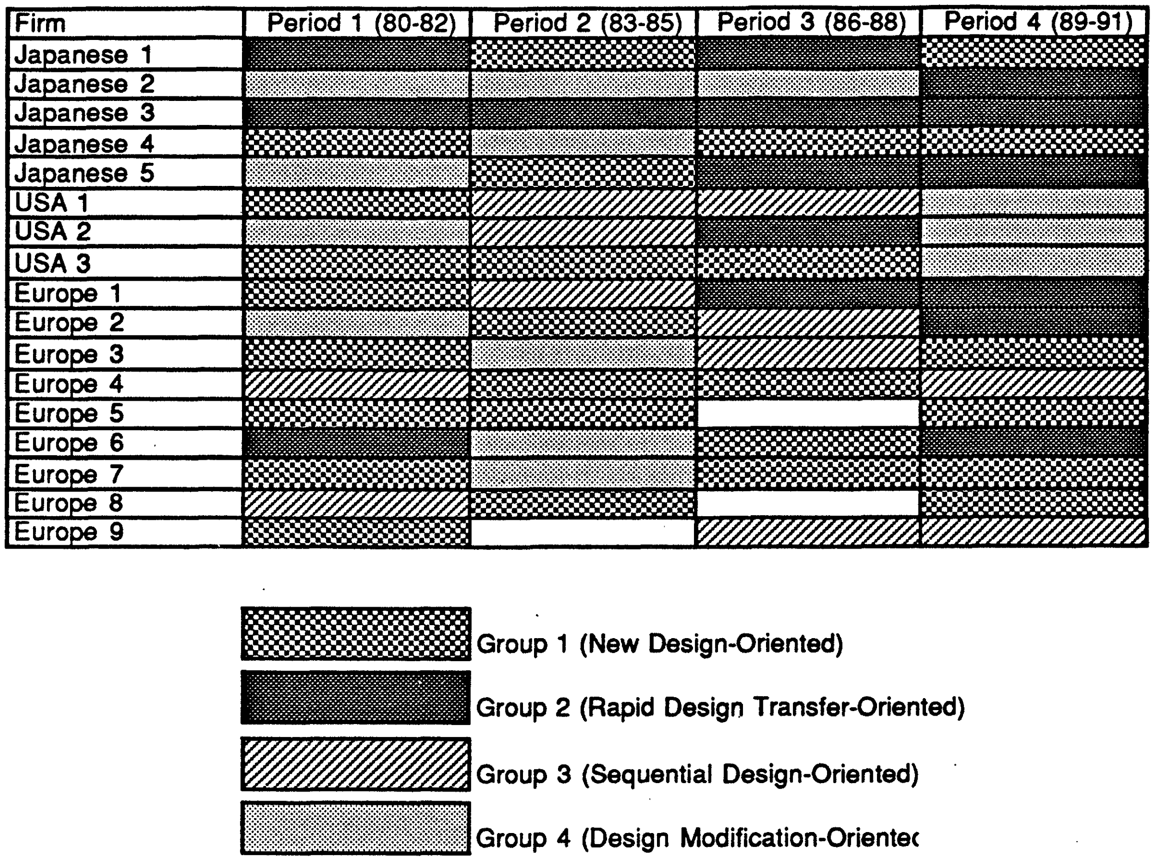
Group 1, but is much newer than that of Group 3 (3.75 years) or Group 4 (5.54 years) firms, recognizing that these results reflect our definitions of the strategic categorization.

Firms in Group 1, during a three year period, developed mostly new designs whenever they introduced new products. This resulted in the lowest average platform design age, 0.37 years, among the four strategic groups. On average, Group 1 and 3 firms gained 3.4% and 9.1% in market share over the 3-year period, respectively, much lower than the firms of Group 2. Group 4 firms, which mainly reused old existing designs and did not often transfer designs across multiple product lines, lost market share.

We realize that the K-means cluster analysis is not the only way to formulate strategic groups. In order to verify this statistical method, we also used a more conceptual method, a flow chart method, which identified four different groups depending on the extent of usage of each multi-project strategy (See Nobeoka 1993 for the actual analysis). There is not any major difference from the results obtained from the K-means cluster analyses.

Table 4 also lists the distribution of data points in each group by firm nationality. There are some patterns for distributions of different strategic groups among the U.S., Europe, and Japan. Data points from the European firms tend to be categorized into Group 1, while more Japanese firms are found in Group 2. In addition, a higher proportion of U.S. and European data points is found in Group 3 than of Japanese data points. These differences suggest that Japanese projects tend to transfer new technologies more quickly and are more frequently categorized as rapid design transfers rather than sequential design transfers. The distributions of the strategic groups for all data points by each of the 17 firms and for each of the four 3-year periods are presented in Figure 7.

Figure 7 Strategic Groups Distribution Among Firms and Periods



There are some characteristic patterns with respect to the distributions of the strategic groups among various firms and regions. For example, a few Japanese firms and European firms have followed the rapid design transfer strategy more than other firms. In addition, some firms only recently started to follow this strategy. However, it is important to note that the major findings discussed above, particularly those relating to differences in market performance among different inter-project strategic groups, do not change when differences in nationalities or periods are controlled, as shown in the regression models in Figure 5. The regression model, using dummy variables for firms in each group, shows that firms in Group 2 gained more market share than those in other groups after controlling for nationality and other variables.

Table 5 Regression Analyses for Market Share ($) with Strategic Groups

Independent Variables	Model 1	Model 2	Model 3	Model 4
Constant	0.00	0.00	0.00	0.00
New Product Introduction Rate		0.55 ***		0.43 ***
Average Platform Design Age		-0.29 **		
Strategic Group				
Group 1 (New Design-Oriented)			-	-
Group 2 (Rapid Design Transfer-Oriented)			0.34 ***	0.28 **
Group 3 (Sequential Design Transfer-Oriented)			0.16	0.06
Group 4 (Design Modification-Oriented)			-0.25 **	-0.24 **
Market Coverage (# of Product Offerings)	-0.21	0.02	-0.14	-0.02
Δ Market share ($) in previous period	-0.27 **	-0.18 *	-0.26 **	-0.23 **
Period (Dummy)				
80 - 82	0.06	0.05	0.16	0.17
83 - 85	-0.15	-0.14	-0.02	-0.01
86 - 88	0.05	0.03	-0.01	0.06
89 - 91	-	-	-	-
Region (Dummy)				
US	-0.19	-0.16	-0.15	-0.19 *
Japan	0.31 **	-0.12	0.28 **	-0.07
Adjusted Squared Multiple R	0.22	0.42	0.42	0.49
Sample Size	65	65	65	65

7 Conclusion

In summary, in order to increase market share, it seems useful for firms to develop new designs and at the same time leverage these new designs quickly in other products rather than only developing a new design or transferring a design slowly to other projects. This result is basically consistent with Roberts and Meyer (1986, 1988, and 1991), who have also found that firms that focus on core technologies and leverage them in new products tend to grow the most in sales. An additional finding in our study is that firms need to leverage core designs across multiple product lines while the core designs are still new and competitive in the market. In other words, the speed with which new technologies are leveraged across multiple projects or products within the firm at least partially determines corporate-level market performance in the form of revenue growth. If firms focus on individual projects for a product line, either through new design or design modification strategies, they are unlikely to grow as quickly as firms following a multi-project strategy based on rapid design transfer.

We realize that the variables used here to predict market performance have limitations. However, this set of data demonstrates that even a limited number of variables related to multi-project strategy explained market share growth reasonably well (adjusted R-squared ranges from 0.42 to 0.49 for the full-variable models in Table 3). Our primary purpose in this section is not to develop a comprehensive model that predicts market share growth. Sales growth, for example, ultimately should result from the ability of a firm to design and build products that customers want to buy, and this relates to quality, price-performance, advertising, product availability, service, and numerous other factors. Among them, design quality may be one of the most important factors that is missing from these models. For example, Clark and Fujimoto (1991) have found that design quality is a better predictor of market performance than development productivity variables.

We believe that average platform design age at least partially captures the design quality of new products, assuming that newer designs are accompanied by more up-to-date and sophisticated features than old designs. This assumption is reasonable because firms usually develop new products to improve old designs. In addition, the standards of a "good" design can change at a rapid pace, especially in such sophisticated markets as the U.S., Japan, and Europe. Because changes in customer tastes and needs, competitive conditions, current fashion trends and social values are so rapid, only new designs may be able to meet a contemporary definition of good design quality. In this sense, the rapid design transfer strategy quickly transfers a new design and good quality across multiple projects and products. In addition, assuming that the change in design quality may be associated with each firm, dummy variables for individual companies may partially capture the extent of the change in design quality. As explained earlier, considerations of the firm differences do not change the results.

Our primary intention has been to propose a conceptual framework for multi-project strategy and to show that rapidly growing firms (in terms of relative market share) seem to adopt a different product-development strategy that also may have specific organizational implications. The typology captures critical project strategy parameters beyond those related to individual projects. These parameters include the way technology and design are inter-related among multiple projects, the speed of technology or design transfer, and their potential influence on corporate-wide organizational structure and processes, as well as their influences on competition in the market. Rapidly growing firms seemed to have the capabilities to plan and implement product strategies that focused on the entire project portfolio, rather than on a single product development project.

Although our framework suggests that in order to implement rapid design transfer, two or more different projects have to be coordinated with each other, this paper does not directly discuss organizational issues. In particular, if rapid design transfer sacrifices individual project performance and productivity because of the inter-project coordination required, the strategy may not be effective. However, our survey of individual projects suggests that the rapid design transfer strategy is actually more efficient organizationally for technology transfer than sequential design transfer or design modification strategies, because only through rapid design transfer can a preceding design be transferred from a base project to a new project with effective task sharing among engineers and mutual adjustments between two or more projects (Nobeoka 1993). In addition, the effective management of multiple projects appears to be organizationally different from managing individual 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. However, this management approach may not be optimal for the effective management of multiple projects at the firm level. Further studies are needed to explore the most effective organizational structure and processes for managing different types of multi-project strategies.

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Appendix

Appendix 1. 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 off-set.
1:	Partially new. Only either wheelbase or track are new with considerations of tire size and wheel off-set.
2:	New. Both wheelbase and track are new with considerations of tire size and wheel off-set.

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 multi-product 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.

Examples of Different Suspension Systems

Traditional Types

• Macpherson Strut Type

The most common type for a front suspension. This system has the simplest structure and has an advantage in production cost.

• Rigid Link Type

The simplest system for primarily rear-wheel drive cars. Because left and right types are not controlled independently, it is difficult to increase the level of cornering performance and stability at the high speed.

• Leaf Spring Type

This type uses a leaf spring, instead of a coil spring. Many vans use this type as a rear suspension. This type has an advantage in the endurance, but may not provide a good drivability and stability.

• Torsion Bar Type

This type uses a torsion bar as a spring. Because the spring is attached directly on the body, it is difficult to insulate vibrations from types, despite its compact and space effective design.

• Semi-trailing Arm Type

This system was once popular as a high performance independent rear suspension. However, because it is difficult for this type to control the degree of toe-in-and-out, more sophisticated systems such as variations of multi-link types have been developed by some manufacturers.

New Technology in the 1980s

• Variations on Double Wishbone Type

The basic concept of the double wishbone type is not new. This type used to be seen only in expensive models and racing cars, because it can be heavy and expensive. Two layers of arms flexibly control tire movements. In recent years, some firms applied new design and technology to this basic structure in order to lower weight and cost and as a result, this type has even been used in less expensive sedans.

Variations include those that use a single arm for the upper or lower arms, instead of wishbone-shaped arms. Some cars have double wishbone suspension system only in rear or only in front instead of for all wheels.

• Variations of Multi-Link Type

The newest concept in the suspension system, using a complicated combination of five or more links for each tire to control all dimensions of tire movements. Some European and Japanese firms have been leading in adopting this type of suspension in primarily their middle- or upper- models.

• Semi-trailing Arm Type with Additional Control Arms and Hubs

In order to control the degree of toe-in-and-out during cornering, changing lanes, and braking, some firms add a sophisticated mechanism such as a toe control hub, additional links, and pillow ball joints.