DESIGN FOCUS:
A STRATEGIC ALTERNATIVE FOR MANAGING PRODUCT DESIGN

by
Debasish N. Mallick*

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* The Carlson School of Management, University of Minnesota, Minneapolis, MN 55455

Phone: 612-626-4773, Fax: 612-624-8804, E-mail: dmallick@csom.umn.edu

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ABSTRACT

Firms faced with a portfolio of inconsistent design tasks often fail to get the best out of their investment in product design efforts. We present the concept of *design focus* as a strategic alternative for gaining competitive advantage through product design. The concept is based on the premise that design task homogeneity facilitates effective information processing and efficient utilization of R&D resources. It induces faster learning, which leads to substantial gain in an organization's competence in dealing with product development challenges. In addition, a focused design strategy benefits from the advantages of managing a smaller portfolio. Design focus is an extension of the concept of focus from the business strategy literature to the new product development literature and it is complementary to the concept of manufacturing and marketing focus. A cross sectional study of forty-four new product development projects provides preliminary empirical evidence supporting the proposed concept, and emphasizes the need for further investigation design focus as a strategic alternative for managing product design. The concept provides a fresh perspective on the management of product design and opens up new directions for future research.

NEW PRODUCT DEVELOPMENT, TECHNOLOGY AND INNOVATION, COMPLEXITY AND UNCERTAINTY, OPERATIONS MANAGEMENT.

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1. Introduction

Product design is a strategic business function that can be managed to gain competitive advantage, yet its management remains a major challenge (Whitney 1988, Fitzsimmons, Kouvelis, and Mallick 1991, Ulrich and Eppinger 2000, Krishnan and Ulrich 2001). One of the challenges of managing new product development arises due to the diversity of product development projects within a firm's product development portfolio (Meyer and Roberts 1986, Wheelwright and Clark 1992, Adler, Mandelbaum, Nguyen and Schwerer 1995, Sanderson and Uzumeri 1997). Faced with increased competition, rapidly changing technology, and market firms are under tremendous pressure for improving the performance of their product development portfolio. Most firms that we have visited during our field study either already have adopted a "standard" new product development process that all of their new product development projects must adhere to, or are in the process of implementing a "best practice" product development strategy based on the latest practices such as concurrent engineering or the use of cross-functional approach (Athahene-Gima and Evangelista 2000, Ramdas and Sawhney 2001). However, such "one-size-fits-all" product design strategy fails to recognize the task diversity within a firm's product development portfolio and leads to ineffective and inefficient utilization of a firm's investments in product development. Therefore, it is not surprising that firms continue to report decline in their R&D productivity and increase in the rate of new product failures (Barrett, Cary, Arndt and Weintraub 2003).

DESIGN FOCUS: A STRATEGIC ALTERNATIVE

During the past decade, new product development has received increased attention both in the academic literature (Clark & Fujimoto 1991, Brown & Eisenhardt 1995, Griffin and Hauser 1996, Krishnan & Ulrich 2001) and in the practitioner literature (Gates 1999, Chesborough and Teece 2002, Welch and Kerwin 2003). While a significant body of this literature has examined the task diversity as a contingent factor for new product development performance, there is an equally significant body of literature promoting the "best practice" techniques of new product development such as team approach, concurrent engineering, and design for manufacture. Scholars have also questioned the contingency approach to new product development and asserted that the "project execution methods are equally effective for product development projects of high or low technology novelty" (Tatikonda and Rosenthal 2000, p. 401). How firms should manage task diversity in a product design portfolio remains an open question.

In this study, we question the "one-size-fits all" approach to new product development and draw upon four streams of management research, i.e., contingency theory (Lawrence & Lorsch 1967a and 1967b), information -processing theory (Galbraith 1973), resource based view (Peteraf 1993) and learning curve (Levy 1965) literature to develop the concept of *design focus* as an alternative for gaining competitive advantage through strategic management of product design. The concept is based on the premise that design task homogeneity facilitates effective processing of information and efficient utilization of R&D resources. It induces faster learning, which leads to substantial gain in an organizations competence in dealing with product development challenges. Additionally, firms with a focused strategy benefits from managing a smaller product development portfolio.

The design focus is an extension of the concept of focus from the business strategy literature (Porter 1980) to the new product development literature and it is complementary to the concept of focus in the operations management literature (Hill 1989) and marketing management literature (Kotler 1984). The concept provides a fresh perspective on management of product design and opens up directions for future research. A cross-sectional study of forty-four new product development projects in the electrical equipment manufacturing industry lends empirical support to the proposed concept and its illustration.

The rest of the paper is organized as follows. In section 2, we review the new product development literature that is relevant to the concept of design focus. In section 3, we identify those factors that cause task diversity in a firm's product development portfolio and the forces that make concept of focus unnatural, counter intuitive, and a management challenge in the new product development context. In section 4, we develop our theoretical arguments and present the concept of design focus in the form of a set of testable hypotheses. In section 5, we describe the methodology that we use to empirically examine these hypotheses, present the results of our analysis and discuss the implications of our findings. In section 6, we summarize our contributions and discuss the limitations of this study. We also discuss the directions for future research and present our concluding remarks.

2. Review of the Relevant Literature

During the past decades, at least four different management disciplines have taken an active interest in the new product development research. These are engineering management (Finger and Dixon 1989a and 1989b), operations management (Krishnan &

Ulrich 2001), marketing management (Griffin and Hauser 1996), and organizational science (Brown and Eisenhardt 1995). A significant part of this body of literature has recognized the importance of task diversity on the product development strategy and examined the effects of project characteristics on new product development practice and performance (Booz, Allen and Hamilton 1982, Clark 1989, Fitzsimmons, Kouvelis and Mallick 1991, Wheelwright and Clark 1992, Kuczmarski 1992, Kuczmarski and Associates 1993, McDonough 1993, Murmann 1994, Eisenhardt and Tabrizi 1995, Hustad 1996, Griffin 1997, Michael, Rochford and Wotruba 2003). For the purpose of this review we classify this body of literature into two categories based on their focus. The first category of studies focuses on the effects of task diversity at the individual project level and the second category of studies, which are still emerging, focuses on the effects of task diversity on the product development portfolio of a firm. Next, we take turns in discussing them.

Attempts to define task diversity using complexity and uncertainty can be traced back to early studies on context and organizational design in the management literature (Lawrence and Lorsch 1967a and 1967b, Galbraith 1973 and 1977, Galbraith and Nathanson 1978). The critical role of complexity and uncertainty in new product development literature has not been as clear. Scholars have used a variety of terminologies to define complexity and uncertainty such as task difficulty (McDonough 1993), product newness (Booz, Allen and Hamilton 1982), content and scope (Clark 1989), high growth rates, technology change and competition (Eisenhardt and Tabrizi 1995) and novelty (Tatikonda and Rosenthal 2000). However, understanding of a concept requires a clear definition and such proliferation of terminology is an indication of the confusion that surrounds these concepts and emphasizes the need for further clarifications.

An operational definition of complexity and its impact on task-difficulty within the context of product design was proposed by Simon (1969). However, a similar operational definition of uncertainty is not yet available in the new product development literature. "Uncertainty is defined as the difference between the amount of information required to perform the task and the amount of information possessed by the organization" in the organizational design literature (Galbraith 1973, p. 5). The early attempt to capture the impact of uncertainty in a product design project by its "newness" was developed by a consulting firm (Booz, Allen and Hamilton 1982) and has become popular in both academic (Yoon and Lilien 1985) and practitioner literature (Kuczmarski 1992, Kuczmarski and Associates 1994). Whether a product's technology is new or related to existing products is useful to know, but it is a simplistic distinction (Nobeoka and Cusumano 1997). Moreover, their framework, which classified projects into six different categories based on product and market newness (e.g., new to the world, new to the company, addition to the existing product lines, improvements/revisions, repositioning, cost reduction), does not recognize the difference between complexity and uncertainty (Griffin 1997).

Fitzsimmons, Kouvelis and Mallick (1991) presented a conceptual framework that explicitly recognized the different roles of complexity and uncertainty in defining a product development project and emphasized the need for a fit between a product design task and strategy. However, their framework was based on case studies and no empirical support for the framework was presented.

Clark (1989, p. 1247) defined project "scope" as "the extent to which a new product is based on unique parts developed in-house" to examine the effects of uncertainty on product development performance in a study of 29 product development projects in 20 firms in the automobile industry in the United States, Japan and Europe. This study reported negative impact of project "scope" on performance measured by lead-time and cost. A subsequent study (Clark and Fujimoto 1991) reported that introduction of new pioneering components did not have any impact on engineering lead-time, engineering hours or product quality. They also failed to find any effect of complexity, as defined by project content (e.g., platform size, market size, and product variety), on performance.

A study of 546 new product development projects by Larson and Gobeli (1989) failed to find any relationship between uncertainty and technical performance, cost, schedule, and overall results. Uncertainty in this study was measured by technology novelty. Another study of 32 small product development projects also failed to find any relationship between the familiarity of technology and product development speed (McDonough and Barczak 1992). However, further study using the same sample reported a negative impact of technical difficulty with product development speed (McDonough 1992).

A study of 72 new product development projects in the computer manufacturing industry found significant association between the use of cross-functional team and product development speed in uncertain environment only after splitting the sample into two segments based on high and low uncertainty. The uncertainty in this study was defined as high growth rates, and high technological and competitive turbulence. The study recognized the effect of project complexity indirectly by controlling for project size

(Eisenhardt and Tabrizi 1995). A study of 29 completed software projects also indicated that a flexible product development process is better suited for projects with high uncertainty (McCormack, Verganti, and Iansiti 2001).

In a cross-industry study of 343 projects in 11 companies, Griffin (1997) recognized the difference between complexity and uncertainty explicitly and examined the effect of project and process characteristics on product development cycle time. The study indicated positive effect of cross-functional team on cycle time for uncertain projects and positive effect of formal product development process on cycle time for complex projects. The complexity was measured by the number of functions and the uncertainty was measured by product newness.

However, in a study of 120 product development projects, Tatikonda and Rosenthal (2000a) failed to find any effect of uncertainty on formality, project management autonomy, and resource flexibility. Further analysis of the same sample again failed to show any association between technology novelty and complexity and overall project failures (Tatikonda and Rosenthal 2000b). However, a negative association between technology novelty and unit cost and time-to-market, and a negative association between complexity and unit cost was reported. Complexity in these studies was measured by technology interdependence, objective novelty, and project difficulty. Uncertainty was measured by technology novelty.

Although the stream of research discussed above has enhanced our understanding of the effects of complexity and uncertainty on product development practice and performance, the focus of this body of literature has been on individual product development projects and they did not take into consideration of the interdependency of the projects within a firm's product development portfolio. Primary limitations of this body of literature are the implicit assumption that product design projects are independent and there is no explicit recognition of the effects of R&D resource on the performance.

Yet, sustainability of competitive advantage is not determined by the success or failure of a single product development project but by a portfolio of product development projects of the firm (Sanderson and Uzumeri 1997).

Meyer and Roberts (1986, p. 811) recognized the problem of managing task diversity within a firm's product development portfolio and hypothesized "that technology-based firms which exhibit a high degree of strategic focus in their new product development activities are more successful than those which have less focus." They use a study of 79 new product development projects from a sample of 10 small-technology based companies to support their claim. The degree of strategic focus was measured by a "newness index" for each firm and success was measured by the growth rate. The concept of strategic focus as conceived in their study is similar to the concept of design focus presented in this paper. However, the study did not include the effects of complexity, and the effect of uncertainty was captured by technology and market newness. Also, the study did not consider the effects of R&D resource on performance.

In contrast to the above findings, Wheelwright and Clark (1992) suggested that a firm should have a small but diverse portfolio of derivative, platform, breakthrough, and advanced R&D projects. They explicitly recognized the constraints on a firms R&D resource and suggested that firms should have a small but balanced portfolio to focus their product development effort. However, their framework (i.e., Aggregate Project Plan) for rationalizing a firm's product design portfolio is based on the product and process newness. The framework is based on case studies and did not consider effects of complexity on R&D resource and performance.

Meyer and Utterback (1995) studied a portfolio of 40 product development projects in a single firm. Their findings suggest that product technology newness has a positive association with development time but they failed to find any association between process technology newness as suggested by Wheelwright and Clark (1992) and Clark and Fujimoto (1991). This study did not include effects of complexity and R&D resource.

Effects of R&D resource constraints were explicitly recognized by Adler, Mandelbaum, Nguyen and Schwerer (1995) by modeling the R&D organization as a stochastic processing network. The results imply that task diversity increases the development time due to congestion and a key assertions the authors make is that there is enough repetitiveness in at least some engineering organization which makes a process model feasible. However, there is no explicit recognition of task diversity in this study.

Nobeoka and Cusumano (1997) studied 210 new product development projects in the automobile industry to examine the importance of technology sharing within a firm's product development portfolio. The result suggests that sharing of technology and speed of technology leveraging are important to sales growth.

We notice that the body of literature related to the effects of task diversity is significant and has contributed greatly to our understanding of the impact of task diversity on new product development practice and performance. Although the first category of literature points us to the association between the task diversity and performance and the second category directs us to the benefits of task homogeneity, findings reported in this literature have often been contradictory (Tatikonda and

Rosenthal 2000a and 2000b), inconclusive (Gerwin and Susman 1996) and, as a result, often been a source of confusion (Griffin 1997). While the effects of uncertainty have been examined at some depth, the findings have been often contradictory. At the same time, effects of complexity have remained relatively under-explored. Moreover, how effects of complexity and uncertainty on performance can be influenced through R&D resource is still an open question.

In this paper, we attempt to integrate these two streams of literature into a parsimonious framework to study the effects of task diversity and R&D resource on product development performance and present the concept of design focus as a strategic alternative for managing a firm's product development portfolio.

3. Task Diversity in Design

Product design is a complex and uncertain process. The process is complex because product design often involves large number of activities that are interrelated to each other. The process is uncertain because these activities and their relationships are difficult to define in advance for a new product design project. Thus, management of complexity and uncertainty are the key challenges in managing product design (Simon 1964, Galbraith 1973, Meyers and Roberts 1986, Clark 1989, Clark and Fujimoto 1991, Fitzsimmons, Kouvelis, and Mallick 1991, Wheelwright and Clark 1992, Griffin 1997, Mallick 2000, Tatikonda and Rosenthal 2000a, 2000b, Eppinger 2001, Ramdas and Sawhney 2001, Krishnan and Bhattacharya 2002, Micheal, Rochford, and Wotruba 2003). Complexity and uncertainty, however, are relative concepts, and they differ widely across industries, across markets within an industry, across various segments within a market, and also within various segments. In this section, we discuss *why* product design projects differ in the levels of complexity and uncertainty, and *how* these differences in levels of complexity and uncertainty, when unrecognized, can lead to a diverse set of design projects and cause a loss of focus in product design effort.

Difference in Core Technology: The technology that is at the core of an industry is usually different. These differences in the core technology are the primary reasons for the differences in the design tasks that are found across industries. For example, the tasks in designing electrical equipments are quite different from the tasks in designing mechanical or optical equipments in terms of the level of complexity and uncertainty. These differences in design tasks that exist across industries due to the differences in their core technology are fairly obvious and quite easy to understand. However, what may not be very clear is how the extent of involvement and the depth of application of a particular type of technology can lead to task differences faced by firms within a given industry.

Difference in Technological Scope: The complexity of a product is driven by its architecture. A product has to satisfy many interrelated, often contradictory, functional requirements. Thus, the complexity of a product is directly related to the number of components in a product and the interactions between these components that are necessary to perform its intended function. Thus, within any product class, design of a system consisting of many assemblies is more complex than design of a single assembly. Similarly, design of an assembly is a more complex task than design of a module, and design of a module is a more complex task than design of a component.

Difference in Technological Change: Uncertainty in a design task results from the incorporation of novel ideas and technology. The level of uncertainty in a design task is defined by the degree of change an innovation brings in comparison to the existing level of performance of a product concept, and also by the frequency with which such changes occur. Thus, within a given product class, the design of a new product platform involves more uncertainty than the design of a derivative of an existing product platform, the design of a breakthrough new product involves more uncertainty than the design of a platform product, and the design of an advanced prototype for new technology infusion involves more uncertainty than the design of a breakthrough product for market introduction.

Differences in Competitive Priorities: Customer satisfaction is the key to successful product design. Firms that can offer products to their customers' satisfaction in a profitable manner are the winners. However, customers differ in their needs and wants. These differences in needs and wants result in differences in "order-winners and qualifiers" (Hill 1989), and lead to differences in competitive priorities across various segments within a given market. These differences in competitive priorities lead to design tasks that are quite different from each other. The design task for a price sensitive segment will require low complexity design to keep the cost of design, manufacturing, and marketing low. However, there are customers within the same market who are willing to pay a higher premium for better quality products. The design task for this segment will call for higher performance and increased features, and is characterized by a higher level of complexity and uncertainty. For example, within the personal computer market, the design task for the price sensitive IBM compatible segment is quite different from the design tasks faced by the designers of the Macintosh products. Macintosh customers in this market segment are not very price sensitive, and are willing to pay, sometimes twice as much, for a more user-friendly product. The task involved in designing the hardware-software combination that makes Macintosh machines user-friendly is very complex and requires a much higher level of innovation than their IBM counterparts.

Differences in the Product Life Cycles: Every product goes through a life cycle that is often described as consisting, of four stages: introduction, growth, maturity, and decline (Levitt 1965). The design tasks to support a product as it moves through introduction, growth, maturity, and eventual decline are different. The design task for introduction of new products involves high uncertainty. The design task at the growth involves improvement on the initial design through feature enhancement and performance improvement, which increases both product complexity and uncertainty. However, as the product moves through the maturity to an eventual decline, design tasks become less and less complex and less uncertain as it generally involves doing only minor design changes.

The design tasks are also different for products with different life cycle lengths. Design task for products with short life cycles such as audio and video equipment require continuous innovation, whereas, products with long life cycles, such as refrigerators and ovens, can wait for radical innovation and can be complex.

Differences across National Boundaries: The design tasks also differ due to differences in social, cultural, and legal requirements that may exist across national boundaries. For example, companies that design electrical appliances for the global market must accommodate differences in power supply specifications and local safety regulations. Sometimes this may require only cosmetic changes, yet involve large sums of money. Phillips, a major appliances manufacturer, spends over $20 million a year just making adjustments to suit its television sets across borders within the European market alone (Meyer 1991). Often this may involve such a major reconfiguration of the basic design as changing the steering column from the left to the right side of the passenger compartment of an automobile.

In addition to the task differences caused by the differences in requirements, the design tasks can also be different across national boundaries due to the differences in the availability of various factors of production such as labor, capital, and materials. For example, most people use kitchen utensils, such as cups and plates, across the world. However, in some countries porcelain and glass are the materials predominantly used. At the same time, in other parts of the world people prefer to use stainless steel cups and plates, while still elsewhere people prefer plastic.

Given the diversity in the design tasks that we have discussed, we find it surprising that firms often attempt to apply a common design strategy to accomplish design tasks that differ widely from one another. The difference in the design tasks across the industry caused by technological differences is generally recognized, and, except for the basic research, companies usually focus their design effort by the industry. For example, 3M company has divided its design center at Austin, Texas as: Telecom division, Audiovisual, Advanced Materials, etc. However, the differences in the design tasks within an industry, and across geographical boundaries are recognized less frequently. Yet, except for a few exceptions, the differences in the design tasks that often exist within a market and within a segment are not recognized at all. Thus, it is very common to find firms using a common design strategy to manage design tasks that are very different from each other with respect to the level of complexity and innovation that needs to be managed. Is it that companies have ignored the management of design, or is it simply that design focus does not emerge naturally due to the presence of centrifugal forces that drive design organization and its management away from a focused design task? This situation is often the result of one or many of the following defocusing forces:

Broad Corporate Mission: The corporate mission of a firm is a statement for its existence. It should reflect the history of the firm, its current business domain and its distinct competitive advantage, and provide directions for future endeavors. Firms often tend to define their corporate mission with respect to the market instead of the products they sell. This is because products may change over time while basic needs and wants of the customer remain relatively unchanged over time. Thus, by focusing on the market instead of the product, a firm may avoid the risk of defining itself too narrowly (Levitt 1960). However, by focusing on a market a firm runs the risk of defining itself very broadly with disparate design tasks. For example, Xerox Corporation, a leading manufacturing company in the USA, has chosen to define itself as a company that "improves office productivity" instead of the maker of "copying equipment" (Kotler

1984, p. 48). However, the task of designing copying equipment is very different from designing a typewriter, a computer or a filing cabinet, any one of which will qualify as a legitimate business that will "improve office productivity" according to the new corporate mission. Firms that define themselves too broadly in terms of the market often run the risk of failing to recognize the diverse nature of design tasks implied by such a broad statement. For example, we believe, IBM, the computer giant, failed to recognize that the design task for the price sensitive microcomputer market is different from their mainframe computers that depend on quality and performance even though they belong to the office equipment market. In fact, industry insiders suspect that IBM probably has not made any money from its PC business since the mid-1980s (Schlender 1991).

Financial Strategy: Firms often attempt to gain financial leverage by reducing financial risks and/or improving the rate of return through mergers and acquisitions. This strategy of merger and acquisitions often forces a firm to enter into unrelated businesses disregarding the differences in the design tasks that may result from such a strategy.

In addition to the above, sometimes strict pay-back rules imposed by the financial executives at the corporate head office, forces business units to accept customized orders that generally brings in higher profit margins. However, customized orders, as the name suggests, increase the diversity of the design tasks that is being faced by a design organization.

Marketing Strategy: Firms often adopt marketing strategies that either call for growth through expansion of market share by introduction of new product lines and/or widening the range of the existing product lines. Sometimes this may involve adding only minor features to the existing products, but often it requires the introduction of products with an entirely new design concept. In either case, they increase the task diversity faced by the design organization. For example, it can be very natural from a marketing perspective for firm selling microcomputers to sell a printer as a peripheral. However, the design task for the microcomputer and the design task for the printer, are quite different from each other in terms of the technology involved, and also in terms of the level of innovation and complexity that define a design task.

As firms widen their existing product range and introduce new product lines, they are forced to carry at the same time, in their product portfolio, products at different stages of their life cycle. For example, a company may have some of their products at the introduction stage, some in the growth, and a few in the decline stage, each set requiring design support at different levels of complexity and innovation. The situation worsens as their product portfolio begins to include products having different life-cycle lengths.

Manufacturing Strategy: The manufacturing strategy of a firm that calls for changes in the production process often changes the nature of the design tasks required to support the new production process. Parts interchangeability is a necessary design requirement for any mass production process such as batch flow or assembly line. Also, robotized manufacturing implies design of parts and components that can be handled by machines without human intervention. A low level of complexity and a high level of innovation characterize the design tasks for such components, whereas the components used in the job shop mode of assembly operation can accommodate a high level of complexity and innovation. For example, while the complex lines of Rolls Royce automobile bodywork can be accommodated by the handiwork of craftsmen working in a job shop, it cannot be reproduced on the assembly line in Detroit.

For various reasons (e.g., shortage of cash, risk in new manufacturing system, avoidance of disruption) firms often adopt a manufacturing strategy that calls for a gradual introduction of new processes. This practice forces designers to design for different types of manufacturing processes requiring different design tasks.

Design Strategy: Design resources are expensive in terms of time and money. Manpower and infrastructural support necessary to develop a design organization are very capital intensive. The cost of running a design organization is dominated by fixed cost of operations such as salaries and wages of the designers, maintenance of hardware and software of the computer and other design support systems, and maintenance of facilities, which makes operation of a design organization amenable to economies of scale. Also, the time required to build a product development organization is generally much longer than the time required to implement a marketing or financial plan. These two factors, in addition to the fact that the managers often find it easier to utilize the existing infrastructure instead of developing a new one, can lead to an increase in the task diversity over time faced by the design organization. In addition, decision to use new technology instead of using existing technology can change the nature of design task overnight. For example, the introduction of semiconductor technology in the musical instrument business has caused fundamental change in the traditional craft way of designing and manufacturing musical instruments. The task of designing microprocessor-based musical instruments requires a much higher level of innovation, and it is far more complex than the traditional design tasks involving woods and strings alone.

Beyond the above reasons a lack of understanding of the design challenges and popularity of business jargons often forces managers to take actions that appears consistent on the surface but results in task diversity in design. Managers unable to face the design challenges and who are looking for panaceas to find an easy way out of their product design problems often embraces the popular techniques of the month such as the team approach, design for manufacture, and concurrent engineering is caused by this phenomenon to an extent. However, these approaches are not a cure for all firms that have neglected their design function over a long period of time, nor do they guarantee successful design. Attempts to implement these approaches without any consideration to the fit of these approaches to the design tasks faced by the firms, some of which may have contradictory requirements, can increase the task diversity faced by a design organization. Any one or a combination of these forces mentioned is generally responsible for an unfocused design strategy.

4. The Concept of Design Focus

Any one or a combination of the factors and forces identified in the previous section can lead to task diversity in a firm's product design portfolio. Unrecognized, such diversity in design tasks will dilute the focus of a firm's design strategy. Consequently, when firms try to apply a standard product design strategy to their entire portfolio of new product development projects with inconsistent design tasks they fail to get the most out of their investments in product design efforts. In this section, we draw upon the extant literature on organizational science and new product development to develop the concept of design focus as a strategic alternative for gaining competitive advantage through product design.

The concept of design focus is grounded in the contingency theory (Perrow 1967, Lawrence and Lorsch 1967, Donaldson 1995, Galbraith 1973) and based on the concept of strategic fit proposed by the design strategy framework in the new product development literature (Fitzsimmons, Kouvelis, and Mallick 1991, Mallick 2000). The framework focuses on the critical role of people, processes, and technologies in product design and emphasizes the need for a strategic fit between (1) design task, (2) design process, and (3) design infrastructure. According to this framework, strategic management of product design requires identification of the design task and selection of a design strategy for its execution. The design strategy consists of two components: a design process to execute the design task and an appropriate design infrastructure to support the design process. It is assumed that the selection and implementation of a particular design strategy has a direct impact on the efficiency and effectiveness with which (1) information is processed and (2) research and development resources are utilized.

Design task is defined by level of uncertainty and complexity of a product design project (Fitzsimmons, Kouvelis and Mallick 1991). A product design project consists of many sub tasks or activities. Complexity of a product design project is determined by number of activities involved in a project and their interdependencies (Simon 1964). However, for most new product development projects, these activities and their interrelationships are not very clear and well understood at the beginning of a project. As reduction of these ambiguities and uncertainties takes place throughout the product development process, activities and their interrelationships becomes clearer and established. Therefore, uncertainty of a product development project is determined by the ambiguity of the activities and their interrelationship at the beginning of the project. The framework assumes that the level of uncertainty and complexity are the primary drivers of a product development project. This is because uncertainty and complexity define the difficulty level of a product design task and determines the need for information processing and R&D resources for its execution (Burns and Stalker 1961, Galbraith 1973, Clark and Fujimoto 1991, Fitzsimmons, Kouvelis and Mallick 1991, Griffin 1997, Tatikonda and Rosenthal 2000a, 200b).

Although both higher level of complexity and uncertainty increases the difficulty of a design task, the way they affect the need for information processing and R&D resource requirements are different. The complexity affects the *volume* of information to be processed and uncertainty affects the *type* of information to be processed. This is because higher level of complexity requires higher volume information processing. However, the type of information to be processed in a complex product design is mostly *deterministic* in nature, where as an uncertain design task requires processing of information that is primarily *stochastic* in nature. Therefore, complexity and uncertainty have different information processing needs and different R&D resource requirements to process these different needs.

Design process is the sequence of activities through which information is processed and research and development resources are utilized during product design. It is the process through which people and technologies are deployed and managed for execution of a product design project. While the number and the variety of the activities involved in a design process are specific to a design project, in the new product development literature these activities are often classified in to four general categories: (1) concept design, (2) technical design, (3) detail design, and (4) manufacturing process design (Dixon and Duffy 1990). These four activities can either be carried out in a sequence or in parallel. Accordingly, in the new product development literature, these two processes are often identified as sequential process (Dixon and Duffy 1990) and concurrent process (Nevins and Whitney 1989). According to the information processing theory (Galbraith 1973), in a sequential process, information is processed through decomposing a design task into smaller subtasks. Integration of the subtasks is achieved through goals, specifications, and policies. Exceptions are handled through occasional team meetings. Therefore, a sequential process is capable of processing high volume of information when such information is deterministic. Accordingly, a sequential process is appropriate for design projects characterized by high level of complexity (Fitzsimmons, Kouvelis, and Mallick 1991, Griffin 1997). On the other hand, when information-processing needs are stochastic, such is the case with product design projects with high levels of uncertainty, exceptions to the goals, specifications and policies arise more frequently than that can be processed through occasional team meetings (Bhattacharya, Krishnan, and Mahajan 1998). Therefore, a concurrent process with the capacity for simultaneous consideration of many design decisions from diverse perspectives becomes appropriate for product design projects characterized by high level of uncertainty (Takeuchi and Nonaka 1986, Fitzsimmons, Kouvelis and Mallick 1991, Griffin 1997). Thus, we notice that these two design processes have two distinct information processing characteristics that are quite different from each other. However, these two processes are the only two extreme points on a continuum and an infinite number of possibilities with different levels of overlaps between the design activities exist. Therefore, whether a design process is sequential or concurrent is determined by the degree of overlap of the design activities during the execution of a product design project. The degree of overlap of the activities determine the volume and type of information that can be processed by a product design process and defines the information processing capability of a design process. Therefore, the degree of overlap is an important management lever for controlling the information processing capability of a design process (Terwiesch and Loch 1999, Joglekar, Yassine, Eppinger, and Whitney 2001). For example, in a stage-gate-process (Cooper 1990), information processing capability is managed through cross-functional implementation of phases between a series of gate reviews. However, we posit that the higher level of information processing capability can only be achieved through increased level of investment in the R&D resources and no single product design process is suitable for managing all levels of complexity and uncertainty.

Design infrastructure is the R&D resources used for supporting a design process. It refers to both human and technological resources deployed to carry out a design task and it consists of two elements (1) design organization and (2) design support systems (Fitzsimmons, Kouvelis and Mallick 1991). The design organization focuses on the way human resources are organized into design teams and the design support systems focus on the technological resources used for supporting the design team. According to the resource based view of strategy (Peteraf 1993), these are the resources available to a firm for gaining sustainable competitive advantage and should not be used in an ad-hoc fashion. In the following section, we examine each one of these two types of resources with respect to their information processing capabilities.

Design organization refers to the way a design team is organized and staffed. There are several ways a product design team can be organized. These are (1) functional organization (2) product focused organization (3) matrix organization. A functional organization is organized by functions and projects move from function to function. Since the human resource is organized by functional expertise, it provides easier information sharing within the function and can process high volume of deterministic information. Therefore, this type of organization is suitable for a complex design tasks. Since human resources are pooled across multiple projects they are better utilized. However, the ability to handle stochastic information is constrained due to the coordination mechanisms used between functions, which are suitable only for processing deterministic information. In a product focused organization expertise from different functions are brought together around the requirement of a project in a dedicated team. Since each product design team has all the human resources it needs to execute a design project, the ability to process stochastic information in real-time is improved and need for coordination is eliminated. Therefore, a product-focused organization is suitable for uncertain design tasks. However, dedicated resources in a product-focused organization lead to inefficient utilization of R&D resources. Therefore, we notice that there is a trade-off between the information processing capability of an organization and the resource utilization. There are several coordination mechanisms reported in the organizational design literature (Galbraith 1973) such as direct contact, liaison roles, task forces, teams, integrating roles, linking managerial roles and matrix design that can be used to balance this trade-off. A matrix organization is one of them. It can be viewed as a functional organization with lateral coordination mechanism. In the new product development literature (Hayes, Wheelwright and Clark 1989), depending on the power and the authority of the project manager, the matrix organization has often been characterized as heavy-weight or light-weight project teams and it was found to be suitable for projects characterized by high levels of uncertainty/complexity and low levels of uncertainty/complexity respectively. The NPD literature (Fitzsimmons, Kouvelis and Mallick 1991, Griffin 1997, Mallick 2000) has also recognized that there exists a one-to-one relationship between a product development process and product development team used for its implementation. For example, a sequential approach requires a functional organization for its implementation and a concurrent approach requires a product-focused team, and a matrix organization can be adjusted to match a design process design activities are overlapped. However, such selection does not happen naturally.

The information processing capacity of a design team is not only affected by the way it is organized but also by how it is staffed. The information processing capacity can be altered by changing the number of individuals in a design team or by changing the composition of a design team or both. However, the ways in which team size and team composition affect the information processing capacity are different. As the number of individuals in a design team increase the information processing tasks are shared by an increasing number of members. The volume of information the team can process will increase as long as the processing needs can be decomposed and coordination burden is minimum such is the case when information is deterministic in nature. Therefore information processing needs of a complex project can meet by increasing the size of the design team. However, an increase in the size of the design team implies an increase in R& D resource. On the other hand the type of information a design team can process is be determined by the composition and expertise of the team members. We posit that a design team's ability to handle stochastic information is determined by the expertise and talents of the team members. Thus, information processing need of an uncertain project is best met by a design team that is staffed by members with high level of education and expertise. Therefore, volume and type of information processing capacity will be determined by the quantity and quality of staffing. We summarize our arguments with the following two testable hypotheses:

Hypothesis 1: *Design task complexity is positively associated with the size of the R&D resource.*

Hypothesis 2: *Design task uncertainty is positively associated with the quality of the R&D resource.*

Design support systems refer to the technological resources used for the execution of a product design project. An extensive set of tools and technologies are available for supporting a product design process, e.g., Project Evaluation and Review Technique (PERT) and Critical Path Method (CPM) (Dean 1985), Design Structure Matrix (DSM) (Eppinger 2001), Simulation Modeling (Adler, Mendelbaum, Nguyen and Schwerer 1995), Structured Planning (Owen 1987), Design Axioms (Suh, Bell and Gossard 1978), Design For Manufacture (DFM) guidelines (Boothroyd and Dewhurst 1983), Design For Analysis(DFA) principles (Suri and Shimizu 1989), Taguchi Method (Taguchi 1978), Computer Aided Design (Burling, Bartels, Barbara, O'Neill and Pennine 1987), Group Technology (Kusiak 1990), Quality Function Deployment (QFD) (Hauser and Clausing 1988), Product Database Management (PDM) (True and Izzi 2002), Product Lifecycle Management (PLM) systems (O' Marah 2002), Rapid Prototyping (RPT) (Pham and Dimov 2001) etc. Although a detailed discussion of these tools and techniques is beyond the scope of this paper, we posit that these tools and techniques are not equally suitable for all design tasks. Their effectiveness for managing complexity and uncertainty are different and their implementation requires different levels of R&D investments. For example, PERT, CPM, and DSM are suitable for managing design projects characterized by high levels of complexity (Eppinger 2001). PERT can handle some levels of uncertainty, but CPM and DSM are not suitable for projects with high levels of uncertainty (Adler, Mendelbaum, Nguyen, and Schwerer 1995). Rapid Prototyping Techniques are suitable for projects characterized by high uncertainty (Pham and Dimov 2001). However, it is an expensive option for complex projects such as an automobile design. Simulation modeling is less expensive under such conditions (Thomke 2001). The use of a particular technology may either facilitate or constrain a design team depending upon the complexity and uncertainty of the design task and, therefore, such decisions should not be made arbitrarily following any best practice prescriptions. Rather, selection of the tools and technology should be contingent upon the project characteristic to ensure efficiency and effective use of these technologies.

A firm's choice of design process, design organization, and design support systems represents its product design strategy, by intention or by default, and defines both the information processing capability and R&D resource requirements. The performance of this product design strategy is determined by the *effectiveness* with which information processing needs of the design task is met and by the *efficiency* with which resources are utilized. However, we have argued that the information processing need and resource requirement of a product design project is defined by level of complexity and uncertainty of the designed task. Therefore, we posit that the fit between design task and design strategy as defined by (1) the information processing need and capability and (2) the resource requirement and resource deployment determines its performance. Therefore, a design strategy that is suitable for low-complexity and/or low-uncertainty design tasks becomes ineffective for design tasks characterized by high complexity and/or a high uncertainty. For example, after their initial success with the Apple II and Apple III brand of personal computer, Apple Computer Inc. embarked on two new product development projects at about the same time: 'Lisa', a high performance product concept, for the high-end ($8,000 - $10,000) office equipment market, and 'Macintosh', a more user friendly concept, for the lower-end ($2,000 - $3,000) home and education market. While the Macintosh project was a huge success, the Lisa project failed (Stanford 1986). We attribute the failure of Apple's 'Lisa' project to their ineffectiveness in managing a design task characterized by significantly higher levels of complexity and uncertainty than that of the 'Macintosh'.

Similarly, a design strategy suitable for high levels of complexity and uncertainty would require a higher level of investment not only in terms of engineering man-hours but also in terms of design support systems. Additionally, implementation of such a design strategy requires a higher level of coordination, control, and expensive management time. Thus, when a design strategy suitable for high levels of complexity and uncertainty is applied to design tasks with low levels of complexity and uncertainty, an inefficient utilization of corporate design resources will result. For example, IBM, the computer giant, had a very powerful design infrastructure (i.e., the design organization and the design support systems). In 1991, it consumed $14.5 billion alone in research, development, engineering and other capital projects. Very few research and development organizations could effectively deal with the levels of complexity and uncertainty in designing mainframe computers as IBM. However, even after the initial success with the PC, XT, and AT, IBM was not been able to compete effectively in the personal computer segment of the market against its PC compatible competitors. This was because “an asset-heavy, people-laden, bureaucracy-ridden aggregate” was not able to carry out the significantly less complex and les uncertain task of designing PCs efficiently. As a result, IBM was forced to price their PCs significantly higher than the competition in a price sensitive market (Loomis 1991).

While Apple Computer Inc. and IBM Corp. failed to retain their market leadership in a market that they helped to create, Dell Computer Corporation, a small player in mid-80’s, has emerged as a major player in same the PC industry. Besides Dell’s “direct model” and “focus on sophisticated computer users” which have received significant attention in the management literature, Dell’s success, in part, is due to the focus of its product design strategy (Margretta 1998). The complexity and uncertainty of each one of its three major product lines, e.g., laptop, desktop, and servers, are quite homogeneous. The homogeneity of the design task is achieved through reduction of component diversity, use of standardized purchased components, and modular product architecture. Dell’s product design strategy allows Dell to offer significantly more product configurations than its competition with R&D budgets smaller than most large computer firms (Thomke, Krishnan, Nimgade 1998). Dell Computer Corporation is an example of how firms can achieve efficiency and effectiveness by focusing their product design effort on a set of homogenous design tasks and gain competitive advantage, even in a market characterized by increased competition and shorter product lifecycles.

Besides the issue of efficiency and effectiveness, there is the important issue of learning that often goes unnoticed by the managers. By focusing an organization's effort on a well-defined set of design tasks, an organization can build substantial competitive advantage through learning. Through repetition, unfamiliar design tasks become routine and organizations develop the capability to deal with a higher levels of complexity and uncertainty. This is because by repeatedly focusing on a set of homogenous design tasks, the organization gains familiarity and builds capability for accomplishing these tasks. This learning results from familiarity and repetition of certain types of tasks. This gain in competence in performing a certain type of design task can be a major source of competitive advantage for a firm (Levy 1965, Badiru 1992, Cusumano 1991, Cusumano, 1992, Nobeoka 1995, Nobeoka and Cusumano 1997, Lapre, Mukherjee and Van Wassenhove 2000, Pisano, Bohmer and Edmondson 2001). For example, Intel corporation had decided early to leave most of its low-complexity /low-innovation DRAM business. Instead, they decided to focus their design expertise on the high-complexity/high-innovation design-rich chips. As a result "the company reported 1990 sales of $3.9 billion and net incomes of $650 millions which works out to a heady 17% profit margin - by far the highest among big chip makers worldwide." Intel is not the only company reaping benefits from focusing their design strategy. A new generation of smaller companies such as LSI logic of Milpitas, California, Cypress Semiconductors etc., is also growing up faster through focusing on the high-complexity/high-innovation design-rich chip market. While at the same time, Japanese manufacturers such as NEC, TOSHIBA, and HITACHI, who lack the design expertise of their American counter-part, have focused on high volume memory chips that are less complex and require less innovation in design. They are also reaping the benefits of focus and doing well in the DRAM market [Schelender (1991)].

In addition to the benefits of improved efficiency, increased effectiveness, and faster learning, design focus also leads to benefits that result from the reduction of the size of the R&D portfolio and organization (Meyer and Roberts 1986, Wheelwright and Clark 1992, Adler, Medelbaum, Nguyen and Schwerer 1995). Some of these benefits that result through reduction of diseconomies of scale include improved communication, better control, and the ability to introduce an equitable incentive systems (Skinner 1974, Rommel, Kluge, Kempis, Diederichs and Bruck 1995). Due to the small size, a focused design strategy also benefits from better interpersonal relationships within the design organization, and facilitates better interaction with other functional specialists outside the design organization such as manufacturing and marketing specialists.

We have seen firms that focus their design effort can gain substantial gain in competitive advantage. Design focus refers to the concept of matching an infrastructure with its design task by reduction in task diversity. The emphasis is not on limiting a design infrastructure to one type of product, it is the issue of task homogeneity that should be the basis of focus. The issue here is a limited and consistent set of design tasks being pursued by each design organization. It is the experience with this set of homogeneous task that provides gain in efficiency and effectiveness of a design strategy. Thus, focusing the demands placed on the design infrastructure will enable resources, efforts, and attention to be concentrated on a defined and homogeneous set of activities, allowing management to identify the key tasks and priorities necessary to achieve a better performance. Thus, design focus means doing a small and consistent set of design tasks better than the competition.

We have used the literature to develop the proposed theory and grounded it using examples from published cases (Eisenhardt 1989, Meredith 1998). However, in order to test the proposed concept empirically, we need to operationalize the concepts of focus, concept of product development performance, and establish a positive relationship between these two concepts. We operationalized the concept of design focus by the relative complexity and relative uncertainty of a product design project. The complexity and uncertainty of the project under study is measured in relation to the complexity and uncertainty of all projects in a firm's portfolio and, therefore, they provide a measure of the degree of the focus of the project under study. Similarly, the concept of project performance is operationalized with relative performance of the project under study with respect to the all product design projects in the firm's portfolio.

*** Figure 1 goes about here ***

Figure 1 provides a visual representation of the proposed approach. We mapped two random product design projects under investigation on to a Cartesian plane defined by relative complexity along the x-axis and uncertainty along y-axis. On this plane, the distance from the origin shows how different the projects under investigation are compared to an average project in the firm's portfolio. Thus, we have a mechanism to measure focus or a lack of it. Now the validation of the proposed concept of design focus requires evidence that farther a project is from the origin worse is its performance. For example, in Figure 1, we expect the Project 2 to have a better performance than Project 1, even though Project 1 is less difficult as defined by lower level of complexity and uncertainty. We summarize our arguments for the concept of design focus with the following testable hypothesis.

Hypothesis 3: *Design focus is positively associated with project performance.*

Control Variables: We have proposed a positive relationship between focus and project performance. However, performance of a product design project can be affected by many factors besides design focus as we have argued here. Controlling for the effects of these factors is essential for understanding the true nature of the proposed relationship. Resource constraint has been identified as one of the critical factors affecting product development performance in the new product development literature. We have hypothesized that the nature of the impact will be affected not only by the quantity but also by the quality. In order to isolate the effects of design focus on performance, we control for the effects of the size of the resources and quality of the resources. It is hypothesized that the both size of the resource and quality of the resource will have a positive effect on project performance.

5. Methodology

In this research, we use a questionnaire based mail survey research methodology. In the following section, we provide a brief description of the methodology that we have used.

5.1 Target Population:

Usefulness of any theory must be judged by its relevance to practice. Thus, we decided to hear the voice of business executives with first hand experience in product development projects. However, the information necessary to address the research problem presented here requires an overall perspective on product development projects. We, therefore, targeted business executives with product development project management responsibilities or higher-level responsibilities in a product development organization.

5.2 Survey instruments:

A survey instrument consisting of 37 items, grouped into two parts, was developed to test the proposed concept. The first part of the survey instrument focused on the demographic information related to the organization of the respondent. It also obtained education, experience, and other background information on the respondent. The second part focused on a project with which respondent had indicated having significant involvement. This section included questions to characterize the project and asked the respondents to provide a comparative evaluation of the project that they are describing with respect to the other projects of the respondents division on a five-point scale (e.g., 5=Significantly higher and 1=Significantly lower).

5.3 Distribution:

In order to reach the target population, we had sent 300 hundred questionnaire to the Automation Forum, a division of the National Electrical Manufacturers Association. The Automation Forum, along with a letter of sponsorship, sent these questionnaires to 300 executives having project management or higher level of responsibilities. A second letter of reminder was mailed three weeks after the original mailing was done. Out of

300 questionnaires, one was returned without any response and 44 completed questionnaires were returned leading to an approximate response rate of 15%.

5. 4 Data:

Table I presents the profile of the firms whose executives had responded to the survey. The annual sales, and the number of employees indicate that the sample had both large and small size firms. The survey covered firms from a wide range of industries within electrical equipment manufacturing sectors. Electronics, computers, information technology, electrical equipment, electro-mechanical equipment were mentioned as the primary line of business of their firms. Thus, the results that follow represent response from a wide range of firms within the electrical equipment manufacturing sectors.

*** Table I goes about here ***

Table II presents the education level of the responding executives. The majority of the respondents (95%) have at least a bachelor's degree. Electrical Engineering (36%) and Mechanical Engineering (18%) were mentioned most often as majors. Other engineering majors mentioned were: industrial engineering, computer science, and ocean engineering. About 18% of the respondents began their career with an undergraduate major other than engineering such as physics, chemistry, biology, operations research, mathematics, or economics. Only a few (6%) began with non-technical majors such as history, political science, or business. More than half of the respondents have a graduate degree either in management, or in engineering, or both. Thus, the survey represents views of individuals with a wide range of educational background and who are familiar with both technical and managerial issues.

*** Table II goes about here ***

Table III presents the experience profile of the respondents. Majority of the respondents have 10 or more years of working experience in the industry. Titles of these individuals frequently included President, General Manager, Director of R&D, Vice President of Operations, Senior VP, and Project Managers. Thus, we feel that our survey was able to reach the target population and their response represents senior level executive opinion.

*** Table III goes about here ***

5.5 Measurement:

Appendix A lists the original question items used as variables for measuring the constructs for testing the proposed concept. Complexity of a product design project was measured by the number activities and their interrelationships. Similarly, as we have explained earlier, uncertainty of a project was measured by the difficulty in defining the activities and their relationships at the beginning of the project. In addition to dollar amount, the investment in product design resource was captured by the size of the product design team, the extent to which the members were dedicated, team composition with respect to expertise, experience and educational levels. A question item was also included to capture the time over which above resources were consumed. Finally, the performance of the product design projects was measured by the return of investment. However, the market success of a product design project is dependent on many factors other than the product design decisions. In addition, the product design projects are often undertaken for reasons other than immediate improvement in return on investment such as gaining entry in to new markets or introduction of new technologies. Three question items related to the satisfaction of the customers, superiors, and project managers were included to account for these non-financial measure of performance of product design projects.

Response to each question item is measured on a five-point perceptual scale anchored at two ends with “one” as significantly lower and “five” as significantly higher in comparison to the average for the responding firm’s product design portfolio. Perceptual scale is widely used in the new product development and other areas of management research. It is found to be no less reliable than the objective measures (Ward, McCreery and Sharma 1998) and, in fact, found to be correlated with objective measures (Vickery Dorge and Markland 1997 and Ward et. al 1994). The data was analyzed using Statistical Analysis Systems Package Version 8.0 (SAS 1979).

Each construct was tested for validity and uni-dimensionality using factor analysis with principal component method and VARIMAX rotation. Rotated factor pattern for each construct is presented in Table IV. Only the variables with a factor loading higher than the recommended minimum of 0.4 (Hair, Anderson and Tatham 1987) were retained for measuring a construct. Thus, question items a and c are used for measuring relative complexity (COMPLEX), question items b and d are used for measuring uncertainty (UNCERT), question items g, h, i and m are used for measuring the quantity of R&D resource (RSIZE) and question items j, k, and l are used for measuring the quality of R&D resource (RQUALITY) and question items n, o, p and q are used for measuring performance (PERF). We also tested each construct for internal consistency and reliability using Cronbach's Alpha or Pearson Product-Moment Correlation coefficients as appropriate. Cronbach's Alpha coefficients are all above the recommended minimum of 0.7 (Nunnally 1978) and correlations are medium to high (Hair, Anderson and Tatham 1997). Thus, we find that these constructs are statistically reliable and valid and we have confidence in using them for further statistical analysis necessary to test the proposed hypothesis.

Each of the forty-four projects under study is mapped on to a Cartesian plane defined by its relative complexity and relative uncertainty. The distribution of the projects on this Cartesian plane as defined by the relative complexity and uncertainty for each project is presented in Figure 2. The origin of x-axis and y-axis is normalized to the modal value to eliminate upward bias in the distribution. The distance from the origin is inversely related to the focus and provides us with a measure of the lack of focus (inverse of focus) of a project under study. We used both euclidean (EUCLDIST) as well as rectilinear (ABSDIST) metrics to measure the distances.

*** Figure 2 goes about here ***

5.6 Results:

The summary descriptive statistics for the data used for the analysis are presented in Table V. Pearson Product-Moment Correlations indicating the relationships between the constructs used for the analysis are provided in Table VI. We notice that all correlations are in congruence with the relationships that we have hypothesized and are statistically significant. Specifically, we notice that complexity is positively correlated with resource size ($p < 1\%$), uncertainty is positively correlated with resource quality ($p<5\%$) and project performance is negatively correlated to the lack of focus as measured by both rectilinear ($p<5\%$) and euclidean ($p<5\%$) distance from the origin as proposed. We also find that project performance is positively correlated with size of the design resources ($p<10\%$) and the quality of the design resources ($p<1\%$). Thus the results of the correlation analysis provide support for all three hypotheses.

We examine this empirical support for the hypotheses further using OLS (Ordinary Least Square) regression method. Table VII presents the set of OLS regression models that we use to study the effects of complexity and uncertainty on R&D resource size and quality by controlling for the effect of uncertainty and complexity respectively. We use Models 1, 2 and 3 to test Hypothesis 1 and Models 4, 5 and 6 to test Hypothesis 2 respectively. Model 1 is statistically significant and shows that complexity (COMPLEX) is positively related to R&D resource size (RSIZE). Approximately 40% of the variation in R&D resource size is explained by this model. Model 2 shows similar results for uncertainty (UNCERT) and R&D resource size, but only 15% of the variation is explained by this model. In Model 3 we bring complexity (COMPLEX) in together with uncertainty (UNCERT). We notice that the coefficient of uncertainty is no longer significant but complexity remains significant. Also, the increase in the percentage of variation explained over Model 1 by including uncertainty (UNCERT) is almost zero. Thus, we have statistically significant results supporting Hypothesis 1.

Model 4 is statistically significant and shows that complexity (COMPLEX) is positively related to R&D resource quality. Approximately 9% of the variation is explained by this model. Model 6 is also significant and shows that uncertainty (UNCERT) is positively related to R&D resource quality. However, statistical significance of Model 6, which includes both uncertainty and complexity, is only at 10% and the coefficients of complexity (COMPLEX) and uncertainty (UNCERT) are not statistically significant any more. Thus we have only a weak statistical support for Hypothesis 2.

Table VIII presents the set of OLS regression models that we use to test Hypothesis 3 by controlling for the effect of R&D resource quantity and R&D resource quality. Model 1 shows the regression of R&D resource size (RSIZE) as the first control variable on performance (PERF). We observe that the regression has low statistical significance ($p<10\%$) but can explain approximately 8% of the total variation in performance. The quantity of resource (RSIZE) is found to be positively related to the performance as hypothesized. In Model 2 we introduce the second control variable, resource quality (RQUALITY) along with resource quantity (RSIZE). We observe that the regression model is statistically significant ($p<5\%$) and can explain approximately 20% of the total variation in performance. The quality of resource (RQUALITY) is statistically significant ($p<5\%$) and positively related to performance, but the effect of resource quantity (RSIZE) is no longer statistically significant. Next, in Model 3 we introduce rectilinear distance (ABSDIST) as our measure of focus along with both the control variables. We observe that the regression model has high statistical significance ($p <1\%$) and can explain approximately 30% of the total variation in performance. The rectilinear distance (ABSDIST) has negative effect on project performance as hypothesized and the effect is statistically significant. The resource quality (RQUALITY) remains a significant determinant of performance. However, the resource quantity (RSIZE) is not significant in the model. In Model 4, we subject the proposed concept through a second test using a different measure of focus, e.g., euclidean distance (EUCLDIST). We observe similar results. The F-value of the model decreases somewhat but the statistical significance of the model remains high ($p < 1\%$) and is able to explain approximately 30% of the total variation in performance. The statistical and practical significance of both the variables remains fairly the same.

5.7 Discussions:

The results that we report in the previous section have several theoretical and practical implications for academics as well as practitioners interested in management of product design. First, the results provide empirical support for our hypothesis that task diversity in product design has a negative impact on product development performance. A managerial implication of this observed negative relationship between task diversity and project performance is that firms can improve their product development performance by reducing task diversity through a focused design strategy. This is the fundamental argument in support of design focus.

We have presented both anecdotal and statistical evidence that lack of focus has a negative effect on product design performance. We have measured lack of focus using different metrics and arrived at the same conclusion. Therefore, the concept of design focus, as we have presented here, is independent of the way it is measured and is fairly robust.

Unlike the previous studies on complexity and uncertainty in new product development literature (Clark 1989, Griffin 1997, Tatikonda and Rosenthal 2000), the focus of this study was on *relative* complexity and *relative* uncertainty of projects in firms' product design portfolio. That is, the concept of design focus does not hold projects with higher level of complexity and/or uncertainty as less desirable than the projects with lower level of complexity and/or uncertainty. In fact, higher level of complexity and/or uncertainty of a product design is often a critical source of competitive advantage (Hagel 1988) and concept of design focus takes that into consideration explicitly. It is the relative complexity and uncertainty of projects in a firm's product design portfolio that leads to task diversity and poor performance.

The concept of design focus is different from the concept of "scope" which is defined as "the extent to which a new product is based on unique parts developed in-house" and suggests strategy of scope reduction as a means for improving performance (Clark 1989, p. 1247). The emphasis of the design focus is not on the reduction of scope of any particular product design project. Instead, the emphasis of design focus is on achieving task homogeneity through reduction of task diversity of a product design portfolio. However, scope reduction can be a means for improving homogeneity of a product design portfolio as suggested by the concept of design focus.

The concept of design focus is also different from the concept of aggregate project plan, which is a strategy for portfolio rationalization on the basis of product and process newness, and emphasizes the need for focusing on a smaller, but diverse, portfolio of product design projects (Wheelwright and Clark 1992). However, a smaller portfolio can be a means for reducing task diversity of a product design portfolio as suggested by the concept of design focus.

Focus is a fundamental concept in business strategy literature (Porter 1980). Focus is also considered critical in marketing strategy literature [Schiller et. al. 1996] as a source of pricing flexibility. Theory development in manufacturing strategy began with the concept of focus (Skinner 1974). However, manufacturing and marketing are only two of the three major functions that are necessary to design, manufacture, and deliver new products to the market. Business strategy is not complete without a design strategy to develop new products in the first place [Fitzsimmons, Kouvelis, and Mallick (1991)]. Therefore, the concept of design focus is complementary to the concept of manufacturing and marketing focus, and reinforces the concept of business focus. Thus, design focus, when combined with manufacturing and marketing focus, can be a source of powerful synergy for achieving business focus and can be a source of significant competitive advantage in the marketplace.

Finally, another important implication of the findings presented here is related to the effect of resources on product development performance. From the analysis of Models 1-6 in Table VII, we notice that complexity has a strong impact on resource size and uncertainty has a strong impact on resource quality. The managerial implication of these findings is that although the processes and organization structures are important, the staffing is an important issue and should be managed carefully. Managers need to pay attention not only to the size of the design team but also to the composition of the design team. Also, such decisions need to be guided by the characteristics of the design project and should not be made arbitrarily. Using the results from Model 1in Table VIII, we can conclude that the quantity of resources used for execution of a product design project has significant impact on the performance and it can be used as a managerial lever. We included financial, human as well as technological resources in our study and this finding is in congruence with existing literature on project management (Meredith and Mantel 1995). However, from the analysis of Model 2, we notice that the quality of the resource has a stronger impact on project performance. Thus, while quantity is important, quality is a more important managerial lever for improving project performance. During our field study, managers have often indicated that the presence of high quality team members are critical for project success at the same time too many individuals without adequate experience and expertise does not help a project much. Thus, the results from this study confirm such anecdotal evidence.

6. Conclusion

The field of operations management has often been criticized for the inadequacy of theory (Swamidass 1991, Schmenner and Swink 1998) and scholars have often emphasized the need for grounded theory development in operations management (Sutton and Staw 1995, Meredith 1998, Malhotra and Grover 1998). In this paper, we attempted to contribute to the theory building in operations management by presenting the concept of design focus.

Firms faced with a portfolio of inconsistent product design projects are often unable to leverage their design efforts to the fullest extent. The concept of design focus argues against the "best practice approach" to new product development and offers a strategic alternative for managing the product design portfolio of a firm. The concept is based on the premise that design task homogeneity facilitates effective and efficient utilization of design resources. It induces faster learning, which leads to substantial gain in an organization's competence in dealing with challenges in product design. In addition, a focused strategy leads to many benefits associated with managing a smaller design organization.

The concept of design focus extends the concept of focus in the business strategy literature (Porter 1980) to the new product design and it is complementary to the concept of manufacturing focus (Hill 1989) and marketing focus (Kotler 1984). Design focus, when combined with manufacturing and marketing focus, can be a source of powerful synergy for achieving business focus and can be a source of significant competitive advantage in the marketplace.

The concept is comprehensive (Whetten 1989) as it synthesizes four streams of research (contingency theory, information processing theory, resource based view, and learning curve literature) to extend the existing body of new product development literature and improve our understanding of the product design process. The theory is parsimonious (Whetten 1989) as it uses only five constructs to provide a clear explanation of a complex phenomenon. The set of hypothesis used to develop the concept is individually and collectively falsifiable (Bacharach 1989) through empirical observation. The utility (Bacharach 1989) of the proposed concept is established through a clear linkage between the concept and the business performance. This is the primary contribution of this paper.

We have also attempted to provide empirical validation of the proposed concept using a study of forty-four product development projects in the electrical equipment segment of the manufacturing sector. From the results of the study we find statistically significant evidence supporting the proposed concept. Findings from the study suggests that design focus and project performance is positively related and this relationship is fairly robust. It also suggests that this relationship between focus and performance is moderated by both the quantity and quality of R&D resources. However, the quality of the R&D resource has a stronger impact on performance than the quantity of the R&D resource. The implication of these findings has important management implications that we have discussed in the previous section. This is a secondary contribution of this paper.

The study suffers from several limitations. The primary limitation of the study results from the small sample size, low response rate, and anonymity of the respondents. Also, no attempt was made to determine non-respondent bias or industry bias in the survey data. This is a manifestation of a larger problem in the subject area related to new product development. New product development information is a critical source of competitive advantage and firms are generally reluctant to share sensitive information with the researchers. This is why researchers are often forced to draw conclusions from a small sample study. Thus, generalizability of such conclusions is often questionable. This research also suffers from such limitation. However, in this paper our objective is not to provide a conclusive statistical evidence of design focus. Instead, our intension is to provide an alternative perspective on the management of product design and to provide some preliminary evidence for generating interest in this direction. Therefore, readers are cautioned against using the findings of this study as evidence for the concept of design focus. Instead, the results should be treated as an illustration of the proposed concept (Sutton and Staw 1999). A large-scale study will be necessary to provide a stronger empirical foundation for the proposed concept of design focus. This is the direction of our future research.

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Figure 1: Visual Representation of Design Focus

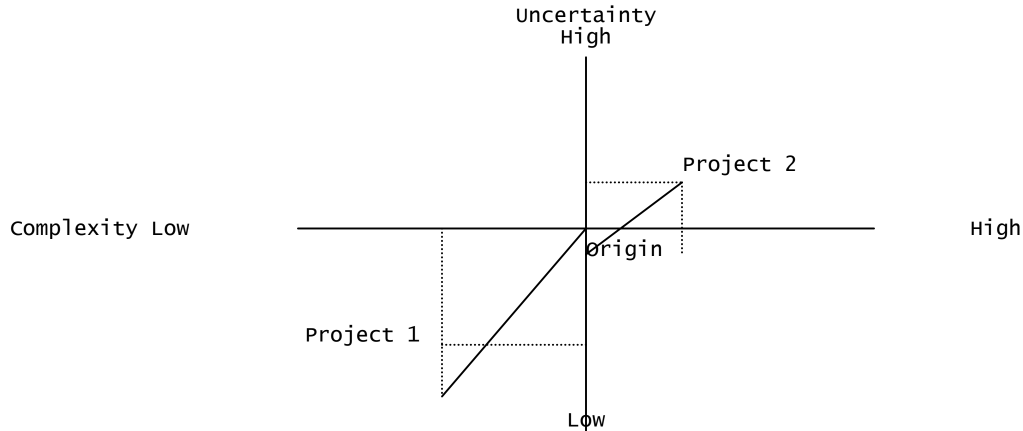

Figure 2: Distribution of the Projects Under Study

```
                     Plot of Uncert*Complex.

Uncert ‚                                        ‚
   5.0 ˆ                                        ‚         B         E
       ‚                                        ‚
       ‚                                        ‚
   4.5 ˆ          A                             A         C
       ‚                                        ‚
       ‚                                        ‚
   4.0 ˆƒƒƒƒƒƒƒƒƒƒAƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒBƒƒƒƒƒƒƒƒƒEƒƒƒƒƒƒƒƒƒCƒƒƒƒƒƒƒƒƒƒ
       ‚                                        ‚
       ‚                                        ‚
   3.5 ˆ                    A         C         A         B         A
       ‚                                        ‚
       ‚                                        ‚
   3.0 ˆ                    B         D         A         A         A
       ‚                                        ‚
       ‚                                        ‚
   2.5 ˆA                             B         ‚
       ‚                                        ‚
       ‚                                        ‚
   2.0 ˆ                              A         ‚
       Šˆƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒƒˆƒ
       2.0       2.5       3.0       3.5       4.0       4.5       5.0

                              Complex

                Legend: A = 1 obs, B = 2 obs, etc.
```

Table I

Profile of the Firms and Division of the Responding Executives

	Sample Size	Mean	Minimum	Maximum	Mode	Median
Firm Sales (in millions)	40	$9,373	$18	$70,000	$500	$950
Firm Size (# of employee)	42	34,913	30	250,000	5,000	4,250
Division Sales (in millions)	26	$1,941	$10	$14,500	$1,000	$280
Division Size (# of employee)	37	3623	8	25,000	500	500

Table II

Educational Background of the Executives in the Sample

Education	Number	% of Sample
Ph.D./D.B.A.	3	7
MBA	17	39
MS Engineering	14	32
BS Engineering	34	77

Table III

Experience of the Executives in the Sample

	Academic		Industrial	
Full Time Working Experience	Number	%	Number	%
None	34	77	0	0
1-5 years	5	11	3	7
6-10 years	3	7	6	14
>10	2	5	35	79
Average	2 years		21years	

Table IV: Question Items and Constructs

Constructs	Question Items (Variables)	Factor Loadings	Cronbach's α and Correlations
Complexity (COMPLEX)			0.45918***
	Number of tasks/activities involved in the project	0.85416	
	The interdependence between the tasks/activities	0.85416	
Uncertainty (UNCERT)			0.64049***
	Difficulty in defining tasks/activities in the project	0.90567	
	Difficulty in defining interdependence between	0.90567	
Resource Quantity (RSIZE)			0.841667
	Dollar amount invested in the project	0.77714	
	Total number of individuals involved in the project	0.93646	
	Proportion of individuals worked full-time (vs. part-time)	0.74209	
	Time taken to complete the project	0.75291	
Resource Quality (RQUALITY)			0.704594
	Proportion of individuals with technical expertise	0.70386	
	Overall level of experience of the individuals in the project	0.86107	
	Overall level of education of the individuals in the project	0.74112	
Performance (PERF)			0.831623
	Return on investment in the project	0.81134	
	Level of satisfaction of the respondent with the project	0.80233	
	Level of satisfaction of the superiors with the project	0.84844	
	Level of satisfaction of the user/customer with the project	0.84463	

*** Statistically significant with $p < 1\%$

Table V: Summary Statistics

Variable	**N**	**Mean**	**Std**	**Minimum**	**Maximum**
COMPLEX	44	3.96591	0.75018	2.00000	5.00000
UNCERT	44	3.77273	0.80301	2.00000	5.00000
RSIZE	44	3.56818	0.89632	2.00000	5.00000
RQUALITY	44	3.71212	0.66508	2.66666	5.00000
PERF	42	3.63690	0.82492	1.75000	5.00000
ABSDIST	44	1.26136	0.77376	0	3.50000
EUCLDIST	44	0.96222	0.56055	0	2.50000

Table VI : Pearson Product-Moment Correlations

Constructs	COMPLEX	UNCERT	RSIZE	RQUALITY	PERF	ABSDIST
UNCERT	0.53697***					
RSIZE	0.63042***	0.38149**				
RQUALITY	0.30615**	0.30284**	0.42706***			
PERF	0.27050*	0.13537	0.28945*	0.42422***		
ABSDIST	-0.20465	-0.24839	-0.11851	0.02157	-0.34361**	
EUCLDIST	-0.26188*	-0.28697*	-0.17744	0.01403	-0.32978**	0.98469***

Statistically significant with *= p<10% ** = p<5% ***= p <1%

Table VII: OLS Regression Models with Resource Size & Quality as Dependent Variables

	RSIZE			RQUALITY		
Independent Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
INTERCEPT	1.96168	1.96168***	0.48029	2.63567***	2.76585***	2.39509***
COMPLEX	0.75322***		0.714484***	0.271425**		0.17882
UNCERT		0.425819**	0.067406		0.25082**	0.16112
N	43	43	43	43	43	43
F	27.70***	7.15**	13.67***	4.34**	4.24**	2.81*
R^2	0.39743	0.14554	0.40002	0.09373	0.9171	0.12066

Statistically significant with *= p<10% ** = p<5% ***= p <1%

Table VIII: OLS Regression Models with Performance as Dependent Variable

Independent Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
INTERCEPT	2.685088970***	1.4782993419**	1.979704676***	2.016588470***
RSIZE	0.268747988*	0.134303143	0.083669568	0.066372000
RQUALITY		0.456026348**	0.487586610**	0.493798808**
ABSDIST			-0.350845129**	
EUCLDIST				-0.457794404**
N	41	41	41	41
F	3.66*	4.80**	5.64***	5.28***
R^2	0.083782	0.197632	0.308159	0.294220

Statistically significant with *= p<10% ** = p<5% ***= p <1%

Appendix A: Part of the Questionnaire used for Analysis

16. Please provide an estimate of the investment in the project in dollars

____

17. Please provide an estimate of the number of individuals involved in the project

____

18. Please provide an estimate of the duration of the project in weeks

____

19. Please provide an estimate of the number of tasks/activities involved in the project

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20. Please provide a comparative evaluation of this project with respect to the other projects in your division on a five-point scale (5=Significantly higher and 1=Significantly lower).

a. The number of tasks/activities involved in the project	5	4	3	2	1
b. The difficulty in defining the tasks/activities at the beginning of the project	5	4	3	2	1
c. The interdependence between the tasks/activities in the project	5	4	3	2	1
d. The difficulty in defining the interdependence between the tasks/activities	5	4	3	2	1
e. The overall complexity of the project	5	4	3	2	1
f. The overall uncertainly at the beginning of the project	5	4	3	2	1
g. The dollar amount invested in the project	5	4	3	2	1
h. The total number of individuals involved in the project	5	4	3	2	1
i. The proportion of individuals that worked full-time (vs. part-time) in the project	5	4	3	2	1
j. The proportion of individuals with technical expertise (vs. business expertise)	5	4	3	2	1
k. The overall level of experience of the individuals involved in the project	5	4	3	2	1
l. The overall level of education of the individuals involved in the project	5	4	3	2	1
m. The time taken to complete the project	5	4	3	2	1
n. The return on investment in the project	5	4	3	2	1
o. The level of satisfaction you experienced with the project	5	4	3	2	1
p. The level of satisfaction your superiors experienced with the project	5	4	3	2	1
q. The overall level of satisfaction the users/customers experienced with the project	5	4	3	2	1
r. The overall of education of the users/customers of the project	5	4	3	2	1
s. The overall level of experience of the user/customers of the project	5	4	3	2	1