This is to certify that the

dissertation entitled

THE IMPACT OF SUPPLY CHAIN INTEGRATION MECHANISMS
ON SUCCESS IN NEW PRODUCT DEVELOPMENT PROJECTS

presented by

Mulmumudi Jayanth Jayaram

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Business Administration

Ram Narasimhan
Major professor

Date 8/11/98

THE IMPACT OF SUPPLY CHAIN INTEGRATION MECHANISMS ON SUCCESS IN NEW PRODUCT DEVELOPMENT PROJECTS

By

Mulumudi Jayanth Jayaram

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Marketing and Supply Chain Management

1998

ABSTRACT

THE IMPACT OF SUPPLY CHAIN INTEGRATION MECHANISMS ON SUCCESS IN NEW PRODUCT DEVELOPMENT PROJECTS

By

Mulumudi Jayanth Jayaram

Recent research has emphasized cross functional integration as a key facilitator of success in new product development (NPD) projects. This dissertation developed and tested a model using *supply chain integration* as a key enabler influencing both planning of the new product and execution of the development process in NPD projects. Supply chain integration was operationalized to include cross functional (for example, between design and manufacturing) and boundary spanning integration mechanisms (such as supplier integration). Product concept effectiveness (a construct capturing the *planning* of the new product), and development process performance (a construct measuring the *execution* of new product development process) were theorized to influence overall project success. Hypotheses drawn from this framework were tested on a multi-industry sample (electronics, communications, semiconductors, and computers) of firms. Data analysis was conducted using regression analyses, partial correlations, confirmatory factor analyses and structural equation modeling.

The results from the data analysis indicated support for the importance of integration mechanisms as enablers of success in new product development projects.

Specifically, infrastructure programs with key suppliers, design proactiveness and 'capturing the voice of the customer' were found to be the most critical integration mechanisms that influenced NPD project success. Integration mechanisms had a differential impact on individual measures of project success. The results support the complementary influence of product planning and development process execution on project success. The contingent influence of market and product related factors on the integration mechanisms → development process performance linkage was also supported. Finally, the results suggest that successful attainment of the goal of reducing time-to-market has associative benefits of attaining goals relating to lower product costs and superior conformance and design quality.

Contributions of this dissertation to practice included identification of specific 'supply chain' integration mechanisms that were significantly related to project success and to the mediating factors (product planning and project execution) of project success. Also, integration mechanisms were shown to have a contingent role in NPD projects. This dissertation contributed to theory by bridging the gap between two established schools (rational planning and problem solving) in new product research by developing and testing a model using constructs from both schools. Contributions to methodology include development of new scales (for example, fit with firm capability) and verification of measurement properties of existing scales at the NPD project level.

This dissertation is dedicated to my father, Mulumudi Jayaram, who would have been extremely proud of this day; to my mother, Sundari Jayaram, whose love and support continues to sustain me; and to my wife, Vasanthi, who has helped me in innumerable ways throughout my graduate study and dissertation work.

ACKNOWLEDGEMENTS

Several people have contributed to the successful completion of this dissertation. I would like to thank Dr. Ram Narasimhan for his support, guidance and direction throughout the doctoral program. He helped me discover the joys of pursuing rigorous and meaningful research. I am fortunate to be one of his students. In particular, I am indebted to him for his unwavering support and encouragement in my search for an academic position.

A special word of thanks to Dr. Roger Calantone for his valuable insight and innumerable pieces of advice on professional and personal issues. I thank Dr. Robert Handfield for his positive support and help in sharpening my empirical skills, and Dr. Gary Ragatz for his cheerful disposition towards me, helpful suggestions during my job search process and support throughout the dissertation process.

I am grateful to the National Association of Purchasing Managers (NAPM) for its support through the Doctoral Fellowship Award. This research project could not have been completed without their generous financial support. A special 'thank you' to the managers and executives who participated in this research project. Several managers went out of their way to help me in this project, by suggesting new contacts and providing timely feedback. I hope that the findings of this research, in some small measure, provides some value for the time invested in this project.

I sincerely appreciate the efforts of Dr. Shawnee Vickery and Dr. Cornelia Droge who involved me in their research projects and also provided helpful suggestions in my job search. I also thank Dr. Robert Nason and Dr. Michael Moch for their overall support and encouragement. I would like to acknowledge the warm support, guidance and helpfulness of Dr. Larry Stimpert, who demonstrated, by example, the joys of teaching and also provided unique insights into the field of business strategy. To the staff of both departments – Sue, Kathy, Lonnie, Laurie, Cheryl, Cindy, Renee and Marilyn – I would like to express my sincere appreciation for all their hard work and enthusiastic support.

My greatest gratitude is to my family – my brothers (Udai and Umakanth), sisters-in-law (Shalini, Padma, Jayanthi and Jyothi), wife (Vasanthi), parents (Jayaram and Sundari), in-laws (RVG Rao and Adhilakshmi) and Annamma. I would like to thank Dr. S.A.N Moorthy (mathematician par excellence) for inspiring me to pursue an academic career. I cherish the joyous moments with all the little bundles of joy in my life – my very own Tara (you are truly a 'star' to me!), Meera (whom I have watched grow into a darling!), Kushal (the energetic and exuberant lad!) and Kunal (the silent toddler!).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (CONT'D)

LIST OF TABLES (CONT'D)

LIST OF FIGURES

CHAPTER 1

OVERVIEW

1. Introduction and Motivation for the Study

The last decade or so has seen a number of sweeping changes that have affected firms in several industries. Hyper-competition, reduction in product life cycles, and increasing need for mass customization are a few changes worth noting. To respond to these changes, firms have used innovation as a source of differentiation, and have sought to increase the pace with which innovation can be introduced to the market. The underlying premise being that agile competitors and in particular, agile product developers have a higher chance of success in the market place. Thus, most firms consider the fast development of new products as a key strategic activity. Indeed, the fortunes of firms are made and dissipated on the basis of product and process innovation. However, empirical evidence suggests that quite a few new products fail in the market place. Booz, Allen and Hamilton (1982) found that the failure rate of new products introduced between 1963 and 1981 was as high as 35%. In a later study, Cooper (1990) confirmed that new products continue to fail at a high rate as they did twenty five years ago. To understand the persistence of this pattern, a number of studies have been conducted to isolate the key factors that enable product development success. Three separate meta analyses have been conducted to synthesize the results of this stream of literature (see, Montoya-Weiss and Calantone, 1994; Brown and Eisenhardt, 1995; and Kessler and Chakarabarti, 1996). Yet, the findings from these three reviews are paradoxical. The broad correlates of new product development project success are not consistent, both in terms of a presence of a relationship and in terms of the strength of their impact, across a variety of settings. All the three reviews call for an integrated examination of broad and new factors that affect new product development success.

Until recently, the dominant view among product development managers was to pay attention to the product development *process*, typically visualized as a series of steps that starts from the inception of a new idea and ends with the introduction of a commercially viable product. Moreover, these series of steps were treated as fixed and the 'quality' of execution of the steps was inferred in terms of financial success of the project. This view is limited because of the absence of a strategic context for evaluating product development project success. More specifically, little was known about why certain projects enjoy higher levels of success than others and whether the successful projects also had products that were planned at the inception stage. This research proposes to use the planning/execution classification, which has strong historical support in the business strategy literature, as a means of more closely isolating the factors that contribute to new product development success.

Using this classification, this research suggests that the success of product development projects depend on two broad issues: product definition-related issues and development process-related issues. Under "product definition," typical research issues are: "What requirements of the customer base does this new product satisfy *uniquely*?" or "Does the firm have the capability to design, manufacture and introduce this product to the market effectively?" On the other hand, "development process" related issues deal with the quality of the execution of the development process, i.e., "What is the impact of the various development activities (from concept to market introduction) on project cost, product quality, and project lead times?" This dissertation will investigate these issues.

The interrelationships among components of development process performance (quality, cost and time to market) is another area that has grown considerably recently. Managers generally are interested in optimizing cost, quality and lead time objectives for new product development projects. However, limited resources (cost, time, personnel etc.) are available to managers to simultaneously minimize cost and lead times, and to maximize product quality. In the literature, one camp (called the trade-off school) has argued that high performance along one dimension of development process performance (for example, superior quality) precludes high performance in other components of development process performance (for example, low cost or low time to market). Representative works from the trade-off school can be found in Cohen, Eliashberg, and Ho (1996), Calantone and Di Beneditto (1996), and Gupta, Brockoff, and Weisenfeld (1992). On the other hand, a parallel stream of research (called the synergy school) has also found that there can be synergies in achieving two of the three development process outcomes. Representative works of the synergy school can be found in Ittner and Larcker (1997), (Flynn,1994), Raia (1991), and Valentino and Christ (1989). This dissertation addresses this inconsistency in the literature.

The previous two research objectives pertained to the performance consequences of effective product planning and effective execution of the development process. The final objective of this research is to identify factors that contribute to effective product planning and execution of the development process. Prior literature has called for the inclusion of integration mechanisms as predictors of success in technological innovation (Shrivastava and Souder, 1987), process innovation (Ettlie and Reza, 1992), and product development (Clark, 1989; Shrivastava and Souder, 1987). This research builds on this body of literature by identifying three kinds of integration mechanisms -- supplier integration, design-manufacturing integration, and customer integration -- as enablers of project success, via the mediating influences of effective product planning and effective execution of the development process. In other words, the three integration mechanisms that collectively span the supply chain are hypothesized to have an impact on product concept effectiveness and development process performance (i.e., product quality, project cost and project lead time performance). Besides the three integration mechanisms, the construct of concurrent process management practices is also hypothesized to influence development process performance. Support for the inclusion of this relationship is provided in the next chapter.

1.2 Research Objectives

This dissertation has three research objectives. One objective of this research is to understand the relative importance of "product definition" and "development process" issues on project success. That is, for a given development project, is product definition more important than development process, or are both equally important? The second objective of this dissertation is to understand how managers of successful product development projects assign priorities to the three objectives of time, cost and quality. The final objective of this research is to identify practices that influence product concept effectiveness and development process performance. Four sets of practices are specifically tested, three of which collectively form supply chain integration mechanisms and the remaining set of practice constitutes the factor of concurrent process management.

1.3 Research Methods

The unit of analysis for this research was a new product development project. Firms from a variety of industries were selected in order to test for contingency relationships across different settings. Data collection was conducted using a survey instrument. The ideal respondent for the survey was specified to be "the person with overall responsibility for overseeing product development projects". The instrument was analyzed for content validity by product development managers from three different industries, before the large scale mail-out. Each manager completed the survey and provided feedback on wording of the items, understandability, organization of the survey and length of the survey. The instrument was refined based on this feedback.

The sampling frame was firms in "high tech" industries which was defined to include firms belonging to the Standard Industrial Classification (SIC) codes 35 to 38 comprising industries such as Industrial Equipment, Computers, Electronics and Electrical Equipment, Motor Vehicles, Scientific Instruments and Medical Devices. Firms belonging to these SIC codes were chosen because they represent industries involved in the manufacture of relatively high value-added and in most cases high technology products. An initial contact list of approximately 5000 firms was generated from two groups of sources – membership lists in professional associations and commercial mailing lists. A detailed description of the procedure followed to generate this list is done in Chapter 4. From the contact list of 5,000 firms, 1,500 firms were selected at random (without replacement) for the initial mailing. A follow up post card mailing after two weeks of the initial mailing and a second mailing after four weeks of the initial mailing yielded 338 usable surveys (24% response rate).

As has been noted in a recent meta analysis of empirical studies in product development projects, researchers have focused on two kinds of links -- between practice and performance, and between construct and performance -- interchangeably (see Montoya-Weiss and Calontone, 1994). Thus, this research also investigated both types of linkages. The data was analyzed using regression analyses and exploratory factor analysis techniques.

1.4 Summary of Major Findings

The first research objective was to investigate the relative role of product concept effectiveness and development process performance on new product development project success. Both product concept effectiveness (as measured by fit with firm capabilities) and development process performance were significantly related to project success. The strength of influence was stronger in the case of development process performance indicating that execution of the new product development process was more critical (as compared to product concept effectiveness) in terms of its impact on project success.

The second research objective was to understand how managers of successful in product development projects assigned priorities to the three objectives of time, cost and quality. All the three indicators of product development process performance (Time, Cost and Quality) significantly influenced project success. Time-to-market was the most important indicator of development process performance in terms of its impact on project success. This was followed by quality and then cost.

The final objective of this research was to identify practices (and factors) that influence product concept effectiveness and development process performance. All the three supply chain integration factors (supplier integration, design-manufacturing integration and customer integration) were significant predictors to both product concept effectiveness and development process performance. As hypothesized, concurrent process management was also a significant predictor of development process performance. The individual practices constituting each factor is described in Chapter 5.

The results indicate that supply chain integration mechanisms significantly impact two mediators of project success, i.e., product concept effectiveness and development process performance. Also, development process performance as a construct and time-to-market as an indicator have a dominant influence on project success. Supply chain integration mechanisms have a strong impact on project success primarily via their intervening impact on time-to-market.

1.5 Contributions of the Study

Contributions of this dissertation to practice include the isolation of supply chain integration mechanisms that are significantly related to project success and mediating factors (product planning and project execution) of project success. Also, the contingent nature of these integration mechanisms on performance are identified. Contributions to methodology include development of a new scale (for fit with firm capability) and verification of existing scales at the product development project level. All the scales were found to have strong measurement properties (reliable, valid and confirmed factor structures).

This dissertation bridges the gap between two established schools of rational planning and problem solving in new product research. Using constructs from both these streams, an integrated conceptual model was developed and tested using empirical data. The results from the data analysis indicated strong support for the importance of integration mechanisms as enablers of success in new product development projects.

1.5 Organization of the Dissertation

This dissertation is organized as follows. In chapter 2, based on the literature in new product development, the framework of supply chain integration in product development projects is introduced. In chapter 3, this framework is explained in detail and research hypotheses are developed from the conceptual framework. Chapter 4 discusses the research design and methodology including the sampling frame and data collection procedures. The description of the sample, psychometric properties of the scales, and the findings from testing of the hypotheses are reported in Chapter 5. The final chapter synthesizes the findings, discusses the primary contributions along with limitations, and provides directions for future research.

CHAPTER 2

REVIEW OF THE LITERATURE

2.1 Introduction

The development of successful new products is a key strategic activity for most firms. Indeed, the fortunes of firms are made and dissipated on the basis of product and process innovation. In a survey of 700 firms (making industrial and consumer products), Booz, Allen and Hamilton, Inc. (1982) found that over a five-year period, new products accounted for an average of 28% of these companies' growth. In a more recent survey Wind, Mahajan and Bayless (1990) reported that 25% of current sales were derived from new products introduced in the last three years. Despite this potential for superlative growth, product development projects are inherently risky. Booz, Allen and Hamilton (1982) found that the failure rate of new products introduced between 1963 and 1981 was as high as 35%. Cooper (1990) later confirmed that new products continue to fail at a high rate as they did twenty five years ago. More importantly, the reasons for the failure of new product projects continue to baffle researchers and practitioners alike. While there have been a number of studies that examined enabling factors that influenced project success, such findings have not been robust enough to accumulate reliable knowledge on new product success. Moreover, most empirical studies in the past used relatively weak research methodologies (such as descriptive statistics, correlational analyses etc.) to examine the research questions of interest. In response to these shortcomings, Brown and Eisenhardt (1995) call for an integrated examination of the links among process performance, product factors and financial performance using multivariate data analysis techniques. They also emphasize the need to include new enabling factors that influence project success.

2.2 Theoretical Perspectives of Product Development

Brown and Eisenhardt (1995) provided a schema for classifying the work in the product development literature (see Table 1). Three distinct research streams were identified: 1) rational planning; 2) communication web; and 3) disciplined problem solving.

2.2.1 Product Development as a Rational Plan

Research in this stream have assumed that product development as a strategic activity that has to be planned in advance, executed well and have top management commitment to the product. This stream contains the largest portion of the reported empirical literature. The underlying focus of this stream is to identify, in a broad sense, the correlates of project success. The research methodologies employed were generally weak and the works were largely atheoretical.

2.2.2 Product Development as Disciplined Problem Solving

This is the most recent stream of research. Product development was treated as an iterative, problem solving activity with many "hit and miss" trials and errors before the development of a successful product. Like the communication web stream, the focus on this stream was also narrow with the objective of explaining complex phenomena such as product vision, characteristics of heavy weight product leaders, and ingredients of an effective product concept.

Table 2.1. Comparison of Research Streams in Product Development

Concepts	Rational Plan	Communication Web	Disciplined Problem Solving
Key Idea	Success via superior product, attractive market, rational organization	Success via internal and external communication	Success via problem solving with discipline
Theory	Mostly atheoretical	Information and resource dependence	Information including problem solving
Methods	Bivariate analysis; single informant; many independent variables	Deductive and inductive; multivariate; multiple informants	Progression from inductive to deductive; multiple informants; single industry, global studies
Product	Product advantage-cost, quality, uniqueness, fit with core competence	—	Product integrity -- product vision that fits with customers and firm
Market	Size, growth, competition	—	—
Senior management	Support	—	Subtle control
Project team	X-functional, skilled	—	X-functional
Communication	High cross-functional	High internal, high external – various types and means	High internal
Organization of work	Planning and "effective" execution	—	Overlapped phases, testing, iterations, and planning
Project leaders	—	Politician and small group manager	Heavyweight leader
Customers	Early involvement	—	—
Suppliers	Early involvement	—	High involvement
Performance (dependent variable)	Financial success (profits, sales, market share)	Perceptual success (team and management ratings)	Operational success (speed, productivity)
Pioneering study	Myers and Marquis (1969)	Allen (1971)	Imai et al (1985)

Source : Brown and Eisenhardt (1995)

2.2.3 Product Development as a Communication Web

In this stream of research the object of investigation is typically the new product development team and most researchers were interested in investigating the communication pattern of members in the team and their impact on team effectiveness. In particular, communication among team members and communication with external members were studied. This stream of research drew strength from information and resource dependence theories.

2.2.4 Development Process Performance – Schools of Thought

Several indicators of development process performance have been studied in the new product development literature. Quality, time to market and cost are the most frequently mentioned measures (Murmann,1994). In order to improve the profit contribution of new product development projects, firms need to balance its efforts towards three objectives - development speed, development cost and product quality (Smith and Reinertsen, 1991). Rosenthal and Tatikonda (1993) also state that the balanced consideration of quality, cost and lead times helps in resource deployment decisions.

In terms of interrelationships among the indicators of development process performance, there are two distinct schools of thought – synergy school and the trade-off school. The synergy school argues that high performance on two or more components of development process performance can be achieved simultaneously. The practitioner press offers several examples of firms that have excelled in multiple measures of development process. For example, companies such as Hewlett-Packard Co. (Hof, 1992;

Teresko, 1991), Honeywell Inc. (Larson, 1988), Intel Corp. (Zipser, 1992), and Xerox Corp. (Raia, 1991) have reported simultaneous improvements in cycle times, product quality, development cost and market share. Some authors have speculated that improvements in time-to-market and quality are positively related. For example, Ittner and Larcker (1997) report that performance benefits of accelerated product development was greater when the perceived quality of the product design was higher. Himmerfarb (1992) argues that concentration on speed to market forces a development team to focus on those elements of a product design that are most related to quality. The business press also cite the cases of Xerox and RCA (Thomson) Consumer Electronics as examples of companies that have made simultaneous improvements in product quality and development lead times (Raia, 1991; and Valentino and Christ, 1989).

In contrast to the synergy school, the tradeoff school posits that all development process measures cannot be attained simultaneously. Improvements in one process measure can only occur at a cost of another. For example, some researchers have reported trade-off relationships between cost and time (Graves, 1989; Mansfield, 1988). An economic model developed by McKinsey and Co. proposed that products that were shipped six months late to market but on budget earned 33% less profit. In contrast, products that were shipped on time but 50 % over budget earned only 4% less profit in the same market (Dumaine, 1991).

The second series of examples of reported trade-offs in the NPD literature is between quality and time to market. Eisenhardt and Tabrizi (1995) report that practices such as rewarding designers for schedule which are deployed to accelerate development time may actually impair quality performance as designers may not adhere closely to product specifications or induce a high level of design quality in the product. Conventional wisdom based on the recent experiences of US manufacturers seems to indicate that fast product innovation and quality represent a trade-off that cannot be simultaneously achieved (Flynn,1994). Murmann (1994) stressed that companies should optimize their development cycle time by considering possible trade-offs between speeding up the process and desired quality. Rosenthal and Tatikonda (1993) conducted a series of seven case studies in the electronics and electrical goods equipment industry and found that four of the seven projects studied traded off time targets to concentrate more on increasing product functionality. Several authors have contended that efforts to reduce cycle time by skipping steps in the development cycle may lead to product defects and manufacturing problems thereby eliminating any benefits from cycle time reductions (Crawford, 1992; Gupta and Wilemon, 1990; Hise, O'Neal, McNeal, and Parasuraman 1989; Ulrich, Sartorius, Pearson, and Jakiela, 1993; Kessler and Chakrabarti, 1996).

The debate on the synergy versus trade-off issue is yet unresolved. Most studies are still prescriptive and lack rigorous empirical verification. The reason why such trade-offs or synergies occur is largely unexplained. Few studies have examined cost, quality and time to market concurrently in their relation to NPD project success. Also, in the NPD literature "quality" has been operationalized to include only conformance quality and not other dimensions of product quality such as design quality. This research seeks to address these issues.

2.

2.

Ei

su

rel

det

inte

Bot

stu

tha

2.3

inte

mar

perf

indu

betw

deve

in su

main

2.3 Determinants of Product Development Success

2.3.1 Meta Analytic Findings

In a recent meta-analytic review of the new product literature, Brown and Eisenhardt (1995) called for the discovery of new enabling factors that determine NPD success. They stressed the need to be on a "discovery" mode for detecting new relationships among the antecedent variables to NPD success. In a meta analysis of the determinants of new product success, Montoya-Weiss and Calantone (1994) call for an integrated examination of broad factors that affect new product development success. Both these reviews emphasize the need for including system wide variables in a single study. The basis for this emphasis comes from the lack of understanding the robust links that affect product success and the conditions under which the relationships exist.

2.3.2 The Integration Literature

A critical review of the literature suggests that some studies have employed an integrative perspective to analyze product development success. Clark (1989) noted that managing practices and policies in an integrated network can contribute to superior performance in product development. In a comprehensive study of the world auto industry, Clark (1989) found evidence suggesting that integration of the capability between upstream and downstream firms is an important determinant of product development success. However, the nature of this desired integration was not explicated in sufficient detail. In a series of in-depth case studies of 12 main competitors in the mainframe computer industry, Iansiti (1995) found that a high systems focus as indicated by technical integration, exposure to systems integration and accumulation of interaction knowledge predicted both lead time and productivity.

Similar recommendations can be found in the innovation literature. Shrivastava and Souder (1987) warn that integration problems can severely inhibit new product development and successful technological innovation. Ettlie and Reza (1992) advocated the simultaneous use of external and internal integrating mechanisms as a way to influence successful process innovation. In particular, they call for a market-directed integration and integration directed at the value-added chain. Market directed integration places particular attention to product designs that are based on customer' needs (Teece, 1988). Internal integration seeks to match internal competencies with the desired competencies to design, manufacture and introduce a customer-driven product.

The importance of integration in NPD projects is gaining attention. For example, Kessler and Chakrabarti (1996) argue that integration enables a faster development process. They proposed that integration can be achieved via four mechanisms: 1) concurrentness in development process or task overlap; 2) design for manufacturability; 3) strength of functional norms relative to shared project norms; and 4) proximity of team members. Using the extant literature, they suggest that faster development is associated with development cost performance (i.e., lower values of cost are 'better'). Similarly, they deduce that faster development can be associated with higher product quality, when the project is focused on customers' needs. Finally, they suggest that faster development processes are associated with higher project success. Thus, integration has been proposed as a key enabler to development process performance and NPD project success.

2.3.3 The Concurrency Literature

The sequential approach of managing NPD projects was largely the dominant view until recently. In this approach, the tasks from concept/idea stage to product launch typically comprising NPD projects were done sequentially. In contrast, the concurrent process management approach considers downstream and external requirements while making upstream decisions. For example, both the product and downstream production process could be designed simultaneously in the early stages of the NPD process. Within the evolving literature relating to concurrency, two themes relevant to this research – proactiveness and joint problem solving – are worth noting. Concurrent process management entails being proactive on downstream oriented decisions. Krishnan (1996), using case study data found that breaking the sequential mind set and pattern of execution requires the concurrent management of downstream phases with upstream phases by using early upstream information. Thus, sharing information on an evolving or dynamic basis appears to be critical for a proactiveness strategy. Yet, a mismanagement of the concurrent approach can lead to expensive and time-consuming downstream rework. The precise balance between proactiveness and reactiveness is still elusive.

Another theme underlying concurrent process management is the notion of joint problem solving among different functional areas that are involved in the NPD process. Swink, Sandvig, and Mabert (1996) using case study data found that in NPD projects developing highly innovative products, joint engineering problem solving was used to a large extent. Trygg (1993), in a survey of Swedish companies which practiced concurrent process methods found that 80% of the companies had formal joint design review meetings among personnel from product engineering, production, marketing and quality assurance. The performance consequences of adopting concurrent process management are not clearly known. It has been maintained that early implementations of concurrent process management techniques reported the benefits of lower product costs and improvements in quality, however, more recent implementations have reported the benefits of lowering time-to-market (Trygg, 1993). On the whole, concurrent process management does appear to positively influence one or more components of development process performance.

2.3.4 The Contingency Literature

Most previous work in the NPD literature have emphasized an unqualified effect of antecedent practices on project success. In contrast, in the evolving contingency school, the view that certain variables operate as moderators has started to emerge. Specifically, in this school, it is proposed that the impact of practices on performance depends on the levels of certain contingency variables. Within this literature, two types of contingencies have been studied – market-related and product-related. Examples of market-related contingencies include stage in the product life cycle and market uncertainty. Song and Montoya-Weiss (1995) , in a study of 788 new products in Japanese firms found that market uncertainty moderated the effect of several technical activities on new product success. Eisenhardt and Tabrizi (1995) found that stage in the product life cycle moderated the influence of supplier involvement on time-to market. Similarly, the effects of product-related contingencies such as product innovativeness and technical complexity of the product have been studied in the NPD literature. Song and Parry (1996) tested a contingency path model that linked product innovativeness and new product success and found that higher levels of product innovativeness actually weakened the direct links between technical and marketing proficiency on new product success. Thus, the contingency perspective is useful for testing several moderating influences in the practice→ performance relationships in the NPD context.

In sum, this dissertation proposes to use the insights relating to meta-analytic findings and developments within three sub-streams within the NPD literature, i.e., integration, concurrency and contingency schools, to propose and test a holistic framework of supply chain integration in the context of NPD projects. The framework is briefly introduced in the next section and details are provided in the next chapter

2.4 Supply Chain Integration Framework of Product Development

2.4.1 Introduction to the Framework

As discussed in the previous section, the findings from recent meta-analyses and recent work in the area of integration mechanisms point towards the need for " a broad brush" exploration of systemic links between integration mechanisms and NPD project success. Fundamentally, this dissertation deviates from previous work in two ways. First, the selection of integration mechanisms proposed to influence NPD project success is guided by a focus on the supply chain. Second, integration mechanisms are hypothesized to influence mediators of NPD project success, and not NPD project success directly. The mediators of NPD project success that were selected are product concept effectiveness (a planning construct) and development process performance (an execution construct). This is similar to the approach taken in business strategy in which the corporate strategy is comprised of a planning and an execution component (Andrews, 1987).

Recent trends in the concurrency literature support the inclusion of concurrent process management as a key construct that impacts development process performance. Similarly, the empirical findings in the contingency school point to the inclusion of key moderating influences in the practice→performance relationships in the framework. In the interest of conciseness, only those practices (concurrent process management and supplier integration) for which the findings are inconsistent are proposed to be tested in this research. In summary, the proposed supply chain integration framework is designed with a view of testing new mediating relationships and controversial moderating relationships among the practice→performance linkages in NPD projects.

2.4.2 Summary of the Research Objectives

Formally, the purpose of this research is to examine whether supply chain integration mechanisms have important performance implications in NPD projects. More specifically, the research objectives are to examine the:

- Impact of supply chain integration mechanisms on new product planning
- Impact of supply chain integration mechanisms on new product development process performance
- Impact of new product planning and new product development process performance on NPD project success

CHAPTER 3

SUPPLY CHAIN INTEGRATION FRAMEWORK

3.1 Definition of Supply Chain Integration

Supply Chain Integration can be defined as an approach or philosophy that concurrently considers market-directed links and internal value chain links. Thus, supply chain initiatives call for an interfunctional and interorganizational focus. Such an emphasis is reflected through the deployment of supply chain management (SCM) practices or integration mechanisms. These mechanisms collectively span the "supply chain" and are evaluated using a systems perspective as opposed to a parochial functional perspective. In this dissertation, a supply chain orientation is used as an organizing philosophy to manage new product development projects.

3.2 Supply Chain Integration Framework

Figure 1 presents the conceptual framework as a basis for investigating the research questions of interest. The rationale for this framework encompasses the following four areas:

- Overall NPD Project Success (Bottom-line Impact)
- Planning of the New Product (Product Concept Effectiveness)
- Execution of New Product Strategy (Development Process Performance)
- Integration Mechanisms

A detailed discussion of the key points in the conceptual framework follows.

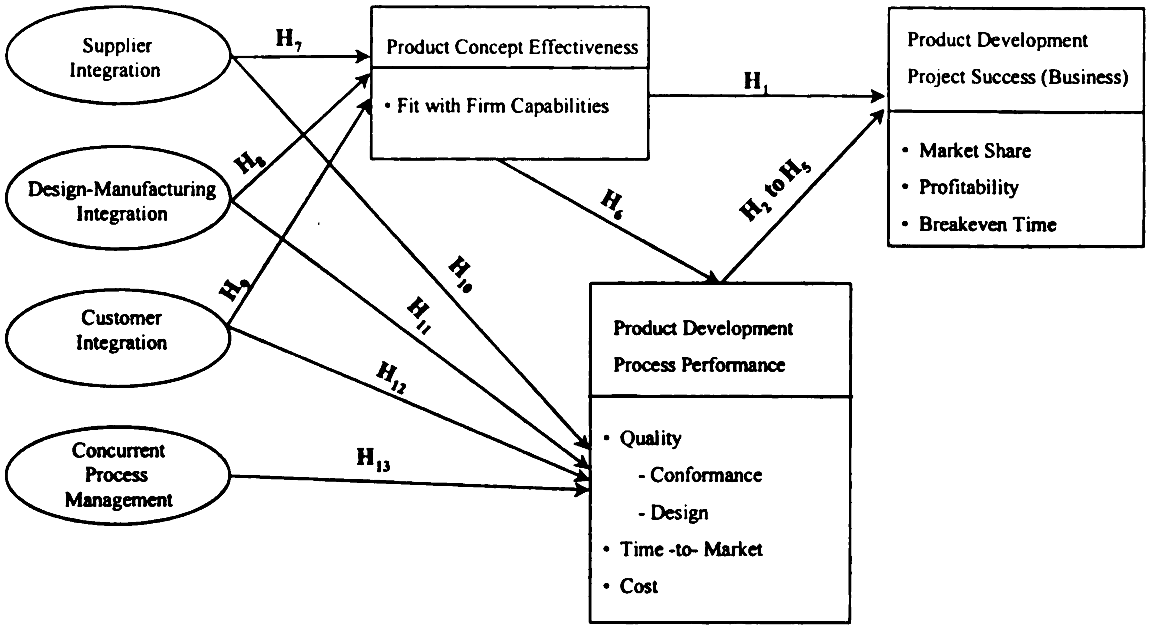

Figure 1: Supply Chain Integration Framework

3.2.1 Product Development Project Success

Success in new product projects is usually evaluated along multiple criteria. Managers are interested in knowing whether the entire product development process was a success or not. This is usually captured as in terms of multiple measures of process performance. Apart from this 'product level' analysis, managers are interested in the overall impact of the development project on the business as measured by profitability, break even point, and initial market penetration. The performance implications of a faster development process is not consistent across studies. Rosenthal and Tatikonda (1993) found in a series of seven case studies in the electronics and electrical goods

equipment industry that it is possible for firms to achieve market and technological success despite the project not meeting its time target.

Support for the operationalization of the construct of product development project success in terms of market share, profitability and break even time exists in the literature. Initial market performance is an important indicator of project performance because several environmental and market variables which are beyond the control of managers influence long term market performance and the impact of time-to-market on long term market performance will be difficult to isolate (Ali, Krapfel and La Bahn, 1995). The profit contribution of the NPD project is also an important indicator of overall success. Certain firms have been known to treat certain NPD projects as 'training' projects which meant that the learning potential from such projects was more important than the potential profitability of the project. But, for a large segment of NPD projects both within a firm and across firms, realized profitability of the project is an important project related objective. Finally, break-even time (defined as the elapsed time from the end of product launch to the start of making profit) has been proposed as an element of project success (Graves, Carmichael, Daetz, and Wilson, 1991).

3.2.2 Product Concept Effectiveness (Planning of the new product)

A key consideration in the formulation of new product strategy is the precise determination of product-related goals. This consideration has been reflected in the literature by phrases such as "product definition", 'product concept' and 'product integrity' (Rosenau, Griffin, Castellion, and Anschuetz, 1996). Product Concept Effectiveness can be defined as the degree of fit between the product's intended image and performance and firm capabilities (Clark and Fujimoto, 1991; Brown and Eisenhardt, 1995). The effectiveness of capturing the product concept is evaluated on the basis of the extent to which the development of the new product is congruent to the current capabilities of the firm.

Fit with firm capabilities has been empirically shown to be correlated with project success (Booz, Allen and Hamilton, Inc., 1982; de Brentani, 1989; Cooper and Kleinschmidt, 1987, Duerr, 1986). Rosenthal and Tatikonda (1993) found in a series of seven case studies in the electronics and electrical goods equipment industry that NPD project planners overlooked the realities of resource availability, most notably those relating to hiring of additional specialists or procurement of special materials and components. This lead to delays in the project because of inadequate appreciation of the time required to meet design specifications with unfamiliar technologies and to coordinate successfully the development work of separate groups including suppliers.

3.2.3 Development Process Performance (Execution of New Product Strategy)

Another key consideration is the execution of the new product strategy. This is evaluated on the basis of an overall impact on the performance measures of the new product development process. There is considerable agreement as to the different steps that are needed to complete the development process. Typically, the following steps are entailed: inception of a new idea, technical and marketing assessment of feasibility, product design, lab testing, prototype development, trial runs, debugging, and mass production. However, instead of focusing on the impact of *all* these *generic* activities on process performance, this study examines the impact of integration mechanisms on development process performance.

Traditionally, development process performance has been measured on the basis of impact on lead times, productivity, and conformance quality. This study would examine the additional measure of design quality because proactive consideration of this measure of quality enhances market penetration via higher customer satisfaction. Instead of productivity, this study would examine development cost performance. Thus, the components of product development process performance included in this study are: conformance quality, design quality, time-to-market and cost.

Conformance quality is the degree to which the product conforms to design and operating needs (Garvin, 1987). It is largely a manufacturing prerogative and assessment of quality performance is typically done after the manufacture of the product or part. Design quality or total quality includes everything about a product that is visible or perceivable to the customer such as technical performance, styling or the match of the product with the target customers' tastes, rather than quality in the sense of manufacturing conformance to specifications (Cusumano and Nabeoka, 1992). Time-to-market is defined as the elapsed time from the beginning of idea generation when the firm decides to develop a new product to the end of product launch when the product is commercially available and managed in a routine manner (Wheelwright, 1988). Synonymous terms that have been employed in the literature include cycle time (Urban and Hauser, 1993), product development time (Lilien and Yoon, 1990), innovation time (Mansfield, 1988), and lead time (Clark, 1989). Several authors have recommended time to market as an important outcome of the new product development process (Ali, Krapfel and LaBahn, 1995; House and Price, 1991; Emmanuelides, 1992; Datar, Jordan, Kekre, Rajiv, and Srinivasan,1997). Product cost measures the unit development cost for the new product comprising the NPD project. It is usually a quantitative measure and fluctuations in actual figures can be attributed to reasons such as design complexity, material composition and assembly costs. A subjective evaluation of actual product cost performance versus budget is needed to make a comparison across diverse products in different firms.

3.2.4 Supply Chain Integration Mechanisms

The product development literature has examined several integration mechanisms or practices that directly or indirectly influence project performance. In a recent review of the literature, Montoya-Weiss and Calantone (1994) found that these practices that influenced project success can be grouped under four factors: strategic, development process, market environment, and organizational. Later, Brown and Eisenhardt (1995) found that seven broad factors affected product development success: suppliers, team composition, team organization of work, team group process, project leader, senior management, and customers. The robustness of findings relating these factors to project success is varied.

In the conceptual framework of this research, selection of the appropriate integration mechanisms or practices have been made with the following basis:

- An emphasis on supply chain management practices
- An interfunctional and interorganizational emphasis
- A focus on practices that have been less studied in the literature

Based on these criteria, the following integration mechanisms or practices are proposed.

Supplier Integration

Supplier integration is an important but often undervalued product development activity (Hartley, Zirger, and Kamath 1996). Fast product developers have reported benefits such as lead time reduction and improved quality more than their slower counterparts through the use of supplier integration (De Meyer and Van Hooland, 1990). Traditionally, supplier management in US companies was characterized by short term arm's length contracts with little or no role in design and engineering (Clark, 1989). In contrast, Japanese manufacturers involved suppliers early in the development process, assigned significant responsibility, and communicated extensively and directly with product and process engineers. Companies like Sun, Tandem and Mips have recognized that design and production of materials and equipment can be no longer accomplished by a single firm and thus have resorted to supplier integration (Saxenian,1991). The Silicon Valley firms caters to a fragmented computer market that consists of distinct markets for super-computers, super minicomputers, engineering work stations, networked minicomputers, personal computers, parallel and multiprocessor computers, and specialized educational computers. This competitive context has led to the flourishing of specialist systems producers and their networks of suppliers.

Research has associated faster development processes with early supplier involvement (Gupta and Wilemon, 1990) and extensive supplier involvement (Clark and Fujimoto, 1991; Imai, Ikujiro and Takeuchi, 1985). Clark and Fujimoto (1991) found that for Japanese car manufacturers supplier involvement accounted for about one-third of the productivity advantages and four to five months of lead time advantages. In another interesting contrast, Swink, Sandvik and Mabert (1996), found in a series of five NPD projects in high tech companies, that early supplier involvement strategy was effective in reducing overall development time for highly innovative products. Hartley, Meredith, McCutcheon, and Kamath (1996), found that the timing of supplier's involvement was significantly related to perceived contribution to product development success. In the same study, they also found a statistically significant relationship between NPD project success and supplier involvement. A recent study found that suppliers direct involvement in buyer's NPD team was the single largest differentiator between most and least successful supplier integration efforts (Ragatz, Handfield, and Scannell, 1997).

The evidence pointing to the benefits of early supplier's involvement (ESI) in NPD projects is not unanimous (Eisenhardt and Tabrizi, 1995). They found that the use of early supplier involvement was positively related to time to market only in the mature mainframe segment of the industry and not in the growing personal computer segment of the industry. Zirger and Hartley (1996) did not find a statistically significant relationship between supplier involvement and product development time.

In a survey of 109 Swedish companies, 79% of the responding companies reported the use of supplier involvement in product development teams, however, this factor did not significantly relate to development lead times (Trygg, 1993). Hartley, Zirger, and Kamath (1996) found in a recent study that overall NPD project performance was significantly related to the percent of suppliers activities that were completed on time. Ittner and Larcker (1997) reported that supplier involvement had a significant negative correlation with development time.

Bonaccorsi and Lipparini (1994), reported the following benefits of early supplier involvement: lower development costs, standardization of components, consistency between design and suppliers capabilities, and reduction in engineering changes, higher quality with fewer defects, improvement in supplier's manufacturing process, availability of detailed process data, and reduction in time to market. Thus, supplier integration appears to play an important role in new product development projects.

Design-Manufacturing Integration

A substantial portion of the new product's committed cost in the early stages of the NPD project can be traced back to the design-manufacturing interface. The integration of the design and manufacturing functions within a firm can prove to be very important in planning a new product and in execution of the development strategy (Rochford and Rudelius, 1992). For example, exchange of information, and consideration of this information in decision making can improve development process efficiency. The literature has pointed to several approaches for coordinating design and manufacturing, either with or without the use of computers. For example, CAD/CAM systems facilitate easy storage, retrieval and processing of technical information which can lead to faster design cycle times (Zirger and Hartley, 1994). Kodak was able to design and launch the Fling Camera in 40 weeks compared to the usual 65 to 80 week development cycle time mainly due to its reliance on a CAD system (Wheelwright and Clark, 1992). In a study of 72 products in the computer industry (Eisenhardt and Tabrizi, 1995) found that the use of

CAD was positively related to time to market in the mature mainframe segment of the industry. Swink, Sandvik and Mabert (1996) cited case study evidence for the positive influence of use of CAD tools to improve design quality performance. In a recent study of Swedish firms, Trygg (1993) reported that the degree of usage of CAD/CAM was significantly higher in groups that reported improvements in development lead times as compared to the groups that did not.

Design for Manufacturability (DFM) is another technique used for integrating the design and manufacturing interfaces in the new product development process. In this technique manufacturing knowledge for each design decision is considered in advance in order to avoid costly iterations and changes later on in the process (Millson, Raj and Wilemon, 1992; Urban and Hauser, 1993). DEC, Xerox and Motorola are some examples of companies that have reported significant reductions (35 to 75%) in the number of components and reductions (53 to 85%) and in assembly costs due to the use of DFM techniques (Brannan, 1990; Lewis, 1986; Welter, 1990). In a series of case studies in the German mechanical engineering industry, Murmann (1994) found that consideration of early manufacturability of the design improved development lead times. Swink, Sandvik and Mabert (1996) found that design for manufacturability positively influenced product cost performance in several case studies of companies in high tech industries.

Quality Function Deployment (QFD) is another technique frequently used to integrate design and manufacturing functions in the NPD process. It is a design approach that ensures that the product meets the customer requirements when it goes into production by a systematic focus on customer attributes throughout the development process (Hauser and Clausing, 1988; Sullivan, 1986; Griffin, 1992). QFD also leads to more fully specified designs so that changes can be made early in the design process. In a recent study of Swedish firms, Trygg (1993) reported that the degree of usage of QFD was significantly higher in groups that reported improvements in development lead times as compared to the groups that did not. Thus, design-manufacturing integration appears to play an important role in new product development projects.

Customer Integration

Customer integration practices help in ascertaining the needs of the customers and translate these needs into product and process parameters in the NPD process. Customer oriented practices have been reported to have organization-wide effects. For example, Ruekert (1992), in an empirical study of employees from different functional backgrounds in five strategic business units of a large diversified company, found a positive relationship between market orientation practices and firm performance. In the NPD literature, Atuahene-Gima (1995), in a study of 275 Australian firms, found a strong positive relationship between market orientation activities and NPD project performance. In this study, market orientation activities were also found to influence development process performance. Later, Gatignon and Xuereb (1997) found a contingent influence of customer orientation on NPD performance. Under conditions of high demand uncertainty, customer orientation practices were found to have the highest impact on NPD performance. In this competitive situation, practices such as customer information generation, dissemination of this information, and detecting degree of responsiveness to customers is highly critical (Jaworski and Kohli, 1994). Thus, customer integration activities have key influences in new product development projects.

3.2.5 Concurrent Process Management

Concurrent process management is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support (Winner, Pennell, Bertrand, and Slusarczuk, 1988; Nevens, and Whitney, 1989). This approach is intended to cause the developers from the outset, to consider all elements of the product life cycle from conception through disposal, including cost, quality, schedule and user requirements. Case study examples of successful implementation (savings of more than 60% in design cycle time) of concurrent engineering programs include Boeing, IBM, HP and Deere and Company (Zangwill, 1993). Overlapping of parts and process design has been reported to decrease manufacturing costs (Takeuchi and Nonaka, 1986). In a survey of 109 Swedish companies, 89% of the responding companies reported that the intent of deploying concurrent engineering practices was to reduce product development time (Trygg,1993). Other motives include : 1) develop more customized products; 2) to reduce product development cost; and 3) to increase suppliers involvement in NPD project.

An efficient organization of concurrent development processes have been shown to be more effective in shortening development cycle times (Eisenhardt and Tabrizi, 1995). Paralleling new product development activities has often been recommended as one of the approaches to reduce development time in different industries (Clark and Fujimoto, 1991; Cordero, 1991; Millson, Raj and Wilemon, 1992, Smith and Reinertsen, 1991). Murmann (1994) in a series of case studies of German companies found that almost all companies studied tapped the potential of either total parallelism between development activities or a certain degree of overlapping of activities. For example, he found that almost all development activities could be started when the previous activity was completed to the extent of 80%. Rosenthal and Tatikonda (1993) conducted a series of seven case studies in the electronics and electrical goods equipment industry and found that reductions in NPD cycle time were achieved through a combination of reducing nonproductive time and increasing the overlap with which tasks are performed. All these studies point to the importance of concurrent process management practices in NPD contexts.

The view that concurrent process management might have a contingent influence on development process performance, as opposed to an unqualified direct impact is starting to evolve. For example, Eisenhardt and Tabrizi (1995) found that overlapping development activities has a significant influence on time-to-market only for new products developed in mature segments as opposed to new products developed in growth segments. Similarly, the level of product innovativeness has a moderating influence on the concurrent process management $\rightarrow$ time-to-market link. For example, Ali et al (1995) discovered that concurrent process management lengthens cycle time in environments reflecting high levels of product innovativeness. The common theme across these studies indicates that concurrent process management practices have a differential impact on time-to market that depends on moderating influences such as product innovativeness and stage in the product life cycle.

The justification for including the different constructs in Figure 1 was discussed in the previous sections. The basis for linking the constructs as is shown in Figure 1 will be discussed under individual hypotheses in the next section. First, the research questions are introduced followed by the discussion of individual hypotheses.

3.3 Research Hypotheses

The conceptual framework in Figure 1 and the discussion in the previous section suggest the following research questions of interest:

- What is the impact of product concept effectiveness and components of development process performance on success of NPD projects?
- Which supply chain integration mechanisms have a significant influence on components of product concept effectiveness?
- Which supply chain integration mechanisms have a significant influence on components of development process performance?
- Do the variables of product innovativeness, market uncertainty, supplier involvement, and technical complexity moderate the influence of supply chain practices on components of development process performance?

First, representative hypotheses concerning the relationships among product concept effectiveness, development process performance and project success are stated. Next, hypotheses for the practices-product concept effectiveness and practices-process performance links are explored. Finally, hypotheses relating to the moderating influences are shown.

a
in
pr
is
im
Ov
wo
fail
Acc

exe
succ
incl
has
proj
to d
incre
freed

3.3.1 Antecedents to Project Success

In an examination of the empirical literature on the determinants of new product performance, Lilien and Yoon (1989) cite 'fit of the new product' to the business context as one of the major determinants of NPD project success. One aspect of the fit discussed in this paper is product fit to firm capabilities. Specifically, they argue that levels of production and marketing expertise are directly related to growth in market share, which is one aspect of NPD project success. Other researchers have also pointed out the importance of assessing and planning for product fit to the capabilities of the firm. Overlooking realities of resource availability can impair the coordination of development work among different functional groups involved in the NPD process and lead to the failure of projects (Rosenthal and Tatikonda, 1993; Sioukas, 1995; Ali et al., 1995). Accordingly, it is proposed that:

> *Hypothesis 1. Fit with firm capabilities is positively related to overall success in NPD projects*

Apart from product planning, (i.e., assessing product fit to firm capabilities), execution of the development process is just as important in its impact on NPD project success. In this dissertation, development process performance is operationalized to include: conformance quality, design quality, time-to-market and cost. Previous research has found positive relationships between development process performance and NPD project success. For example, Smith and Reinersten (1991) report that shorter cycle times to develop and introduce new products increases sales through extended product lives, increases market share through pioneering, and increases profitability through pricing freedom and economies of scale. Similarly, Rosenau (1990) found that faster development was associated with project success defined in terms of higher sales and profits.

Individual positive relationships between quality, time and cost, with project success has also been reported in the literature (see Larson, 1988; Zipser, 1992; Flynn, 1994; Ittner and Larcker, 1997). Contrary findings in the relationship (negative) between components of development process performance and project success is also reported (Murmann, 1994; Eisenhardt and Tabrizi, 1995). As there is more consistency in the pattern of positive relationships, the following are hypothesized:

> *Hypothesis 2. Conformance quality performance is positively related to overall success in NPD projects*
>
> *Hypothesis 3. Design quality performance is positively related to overall success in NPD projects*
>
> *Hypothesis 4. Time to market performance is positively related to overall success in NPD projects*
>
> *Hypothesis 5. Development cost performance is positively related to overall success in NPD projects*

Finally, product concept effectiveness is proposed to influence development process performance. On a temporal scale, this relationship makes sense because an early assessment of fit between existing capabilities of the firm and desired capability level as dictated by the new products is necessary for obtaining superior development process performance (see De Brentani, 1989; Cooper and Kleinshmidt, 1987; Duerr, 1986). Accordingly, it is suggested that:

> *Hypothesis 6. Fit with firm capabilities is positively related to development process performance in NPD projects*

3.3.2 Antecedents to Product Concept Effectiveness

The literature has suggested a number of practices or enablers of capability development which can be useful in managing new product development projects. In this research, the practices of supplier integration, design-manufacturing integration, and customer integration, which span the supply chain, are hypothesized to affect product concept effectiveness which is measured as the product's fit with firm capabilities. Support for such a supply chain perspective can be found in the works of Ettlie and Reza (1992) and Shrivastava and Souder (1987). The fit with firm capabilities construct can be viewed as a measure of capability performance. In this sense, the next set of hypotheses examine the capability enabler - capability performance relationships. Thus, it is hypothesized that:

> *Hypothesis 7. Supplier integration practices are positively related to fit with firm capabilities*
>
> *Hypothesis 8. Design-manufacturing integration practices are positively related to fit with firm capabilities*
>
> *Hypothesis 9. Customer integration practices are positively related to fit with firm capabilities*

3.3.3 Antecedents to Development Process Performance

In this research, the supply chain practices of supplier integration, design-manufacturing integration, customer integration, and concurrent process management are hypothesized to affect development process performance. Support for a positive relationship between these individual supply chain practices can be found in the literature (see Clark and Fujimoto, 1991; Cordero, 1991; Handfield, 1994; and Hartley et al., 1996). A smaller subset of works have found that certain supply chain practices such as supplier integration and concurrent process management practices can actually impair development process performance (Eisenhardt and Tabrizi, 1995; Crawford, 1992). Based on the stronger support of the positive relationships, it is proposed that:

Hypothesis 10. Supplier integration practices are positively related to development process performance

Hypothesis 11. Design-manufacturing integration practices are positively related to development process performance

Hypothesis 12. Customer integration practices are positively related development process performance

Hypothesis 13. Concurrent process management practices are positively related to development process performance

3.3.4 Hypotheses relating to Contingency Relationships

While the relationships discussed so far examine the mediating relationships between enablers of project success, and project success, the following section investigates potential moderating influences of supply chain practices on development process performance.

<u>Product Innovativeness</u>

The role of product innovativeness in NPD projects deserves further investigation. This is so because of inconsistent findings in the literature. Products that are high and low in innovativeness, have been found to be more successful as compared to moderately innovative products (Kleinschmidt and Cooper, 1991). In contrast, Ali et al (1995) postulated that increasing product innovativeness tends to lengthen cycle time. This is so because higher levels of innovativeness require a "trial and error" approach before the final product concept is crystallized. In contrast, products with low levels of product innovativeness are more stable and require less coordination between different functions involved in the NPD process and thus are amenable to process concurrency. The common theme across these studies seem to indicate that concurrent process management practices have a differential impact on time-to market that depends on the level of product innovativeness. Accordingly, we hypothesize that:

> *Hypothesis 14: Concurrent process management practices have a positive influence on time to market only for products that are low on levels of product innovativeness.*

Technical Complexity

Technical complexity of a product is defined as the extent to which new knowledge, materials, or components are embodied in the product (Capon and Glazer, 1987). Products that are high in technical complexity could introduce complications into the development process and therefore tend to lengthen time to market. In fact, Ali et al (1995) found that technical complexity had the strongest delaying effect on cycle time for developing new products. This is also consistent with the finding of Cooper (1979) in a study of new products in the chemical industry. Practices geared to accelerate product development such as concurrent process management may have a lower effect on cycle time for products that are highly technical. Thus, it can be argued that:

> *Hypothesis 15: Concurrent process management practices have a positive influence on time to market only for products that are low on technical complexity of the products.*

Market Uncertainty

Market uncertainty or risk may also moderate the impact of concurrent process management practices on time to market performance. Support for this view can be found in Cooper and Kleinschmidt (1994) who report that in markets with higher levels of competitiveness (and thus, uncertainty), the impact of acceleration practices on cycle time is adverse. Customer driven processes cannot be hastened because the needs of the market are also slowly evolving in this kind of a context. In contrast, markets with lower levels of uncertainty may be prime candidates for employing concurrent process management practices and competing on the basis of time to market. Thus, it is proposed that :

> *Hypothesis 16: Concurrent process management practices have a positive influence on time to market only for markets with lower levels of market uncertainty.*

Stage in the Product Life Cycle

Apart from concurrent process management, there is growing support for the contingent influence of supplier integration practices. For example, stage in the product life cycle has been shown to have an important bearing on the usefulness of the strategy of early supplier involvement as a means to improve time to market. Early stages of the product life cycle are characteristic of high uncertainty and complexity. In this stage, early involvement of suppliers can actually hamper development lead times (Eisenhardt and Tabrizi, 1995). Similar findings are reported by other researchers (Hartley et al., 1997; Birou and Fawcett, 1994). In sharp contrast, Eisenhardt and Tabrizi (1995) found that the use of early supplier involvement was positively related to time to market in the *mature* mainframe segment of the industry. Thus, it is proposed that :

> *Hypothesis 17 : Early supplier involvement practices have a positive influence on time to market only for products that are in the maturity stage of the product life cycle.*

In this chapter, the research framework of supply chain integration was introduced, key constructs were operationalized and hypothesized relationships among the constructs were presented. In the next chapter, the research design and methods used to develop the survey instrument are described. Details regarding data collection procedures are also provided.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

In the previous chapters, the research framework of supply chain integration was introduced, key constructs were operationalized and hypothesized relationships among the constructs were presented. The purpose of this chapter is to describe: (1) the research design including the sampling frame and unit of analysis; (2) the methods used to develop and pilot test the survey instrument; and (3) the data collection procedures.

4.1 Research Design

The research framework in this dissertation is based on the new product development project as the unit of analysis. The characteristics of new products have substantial variation across different industries. Indeed, within a single industry also, there could be considerable variation. As the research questions in this dissertation are exploratory with reference to the current state of knowledge, care was taken to ensure considerable variety among the industry groups with respect to the stage in the overall industry cycle. For the purpose of discussion, two ends of the continuum from introduction stage to maturity stage, are worth noting. Firms in the introduction stage were selected from industries such as electronics, electrical equipment, semiconductors and medical instruments. On the other hand, firms in the mature segment of the product life cycle were selected from the auto industry (including auto components industry), chemicals industry and pharmaceutical industries.

The purpose of this research was to identify relationships among concepts that have received limited attention in the literature. In the realm of the philosophy of science, this approach is called the 'discovery' mode of creating knowledge (McCall and Bobko, 1991). In particular, McCall and Bobko (1991) point to the usefulness of large sample studies for discovery. Accordingly, a multi-industry population that provides a variety of contexts was deemed appropriate for selecting the sampling frame. As noted by Bobko, Karren and Kerkar (1987), an orientation towards discovery facilitates the inquiry into research questions that seek to find reasons for variability. One of the principal objectives of this dissertation is to understand variability in success rates of new product development projects. Especially at the new product development project level, the variety across industries and within industries (indeed, within the same company) is considerable. Also, a multi-industry sample facilitates testing of contingency relationships such as the moderating roles of stage in the product life cycle, market uncertainty and product innovativeness on concurrent process management→ time-to-market relationship.

4.1.1 Sampling Frame

The sampling frame was firms in "high tech" industries which was defined to include firms belonging to the Standard Industrial Classification (SIC) codes: 2833 to 2836; 2873 to 2875; 2879, and all industries under general SIC 35 and 38. Examples of industries included: Chemicals, Industrial Equipment, Computers, Electronics and Electrical Equipment, Motor Vehicles, Scientific Instruments and Medical Devices. Firms belonging to these SIC codes were chosen because they represent industries invol

techn

proje

appro

firms

firms

4.1.2

projec

years

been

invest

(Mont

Chakr

more

specif

from t

of ana

be use

involved in the manufacture of relatively high value-added and in most cases high technology products. The desired range for the final sample size was between 200 to 250 projects. Based on a conservative estimate of five percent as the response rate to surveys, approximately 5000 firms would have to be contacted. As it can be expected that several firms, especially leading edge firms, pursue multiple NPD projects, the final number of firms that need to be contacted was expected to be less than 5000 firms.

4.1.2 Unit of Analysis

The unit of analysis was to be a recently completed new product development project. Respondents were asked to identify a completed project within the last three years for which at least one year had elapsed since the launch of the new product. As has been noted in all three recent meta-analyses on product innovation, researchers have investigated product innovation issues using the firm or project as the unit of analysis (Montoya-Weiss and Calantone, 1994; Brown and Eisenhardt, 1995; Kessler and Chakrabarti, 1996). For this research, treating the project as the unit of analysis makes more sense because practices and their influence on project success tend to be more specific and readily identifiable than the firm as the unit of analysis. Also, the findings from this research can be compared to similar works that have used the project level unit of analysis. Finally, this research can contribute to the development of scales that could be useful in future research which treat the project as the unit of analysis.

4.2 Research Methodology

4.2.1 Survey Development

To investigate the proposed research questions and associated hypotheses, a survey instrument was developed (see Appendix 1). The items in the instrument were developed by resorting to available scales (to the extent possible) from purchasing, operations, marketing and NPD literature. The questions for the constructs in the conceptual framework were asked largely using qualitative or perceptual scales (10-point Likert scale). A few quantitative measures pertaining to size and cumulative person hours spent on the project were also included in the questionnaire. While it is desirable to collect objective performance data, in the interest of obtaining a high response rate, very few items that asked for quantitative or "hard data" were included in the survey instrument. This problem is especially relevant for new product development projects which are usually considered to be highly proprietary and confidential. Therefore, most researchers who have tried to obtain "hard data" in the past had to settle for a low sample size. In this research, an approach of "casting a wide net" to gather data from a variety of contexts was deemed more appropriate.

The 10-point Likert scales was used as opposed to the popular 5 or 7 point scales in order to minimize the response time and effort to the managers. Managers can easily relate performance on an item when it is expressed as a percentage. A similar approach has been followed in the NEWPROD project questionnaire which was first developed by Cooper (1979) and then used in several empirical projects since then. In addition to items relating to the conceptual model, descriptive information at the project level and information relating to the following (moderating) variables were also included:

- Technological Intensity of Product (Incremental versus Breakthrough)
- Product Innovations (Low/High)
- Market Uncertainty (Low/High)
- Stage in the Product Life Cycle (Introduction/Growth/Maturity)

Input of experienced faculty members with research interests in NPD from several universities was sought for comments and suggestions for improving the survey instrument. The instrument was then pilot tested on product development leaders in three companies. The three companies varied in terms of the industry (Medical Devices, Aerospace Equipment and Automotive) and type of product (ICU unit, navigation control system and luxury car) being developed. Interviews in two of the three companies were carried out on site. For the third company, the survey instrument and accompanying information on the research project was mailed to the project leader who filled out the survey and provided written feedback via fax and e-mail.

The general form of discussion for the on-site interviews progressed through a "funneling process" (see Handfield and Ghosh, 1994). First, the general market for the new product as perceived by the firm were discussed. In all the cases, this led to a discussion of a specific new product that was launched recently. This was followed by a discussion of the key indicators of new product development project success that the firm emphasized. The relationships among the three performance indicators of NPD projects, i.e., cost, time-to-market and quality as perceived by the firm was then discussed. Next the discussion centered around the role of product planning (specifically, the fit with firm capabilities) on project success. Finally, the role of integrative mechanisms were discussed. Once the project leader was focusing on a particular project, the discussion was allowed to become less directed. However, all of the issues described above were covered in all the three cases.

The discussion started broadly at the firm level but ended in discussions on specific project related practices that were implemented by the firm. The on-site interviews took approximately 90 minutes to complete. One of the site participants distributed the survey instrument within the company to project leaders in other divisions. In all ten completed surveys were received as part of the pilot study. All the participants in the pilot study were specifically asked to comment on: (1) items and practices that are not currently in the instrument but ought to be included; 2) items and practices that do not belong and ought to be excluded; (3) understandability of terms used (and directions) in the instrument; (4) the "doability" of the project, i.e., whether the scope of the project as indicated by the length and complexity of the questionnaire was narrow or broad; (5) the relevance and usefulness of the research project; and (6) the face validity of linkages shown in the supply chain integration framework (Figure 1). Each project leader completed the questionnaire and provided feedback on the above issues. The feedback from the participants indicated strong interest in the project, high content validity of the conceptual framework, but considerable doubt about the scope as indicated by the length of the instrument. The pilot survey instrument was modified based on this feedback. For example, sections that were not related to the conceptual framework of Figure 1, but were included for post-dissertation research projects were eliminated. Long sentences and "wordy" phrases were removed. In some cases, terms were followed by short explanations to improve clarity. The revised instrument was then used for large–scale data collection.

4.2.2 Data Collection Procedures

For the large scale mail-out, an initial contact list of approximately 5000 firms was generated from two groups of sources – membership lists in professional associations and commercial mailing lists. The membership list of the following three professional associations were used: National Association for Purchasing Management (NAPM), Product Development Management Association (PDMA) and Institute of Electrical and Electronics Engineers (IEEE). For the commercial mailing list, a customized list of potential firms to be included was generated using the following criteria: 1) firms should belong to the SIC Codes 35 to 38; 2) the number of employees should exceed 100; and 3) the annual sales of firms should exceed one million dollars. The initial contact person for the professional organizations were high level executives within their functional areas. The typical titles included: Director of Purchasing for NAPM; Director of Product Development for PDMA and Director of Engineering for IEEE. For the commercial mailing list, the initial contact persons were specified to include top level executives in technology, R&D and product development. Typical titles of contact persons included: Chief Technology Officer (CTO), Director of Research and Development, and Director of Product Development. While compiling the initial list, care was taken to remove from the list service firms, consulting organizations, purely research and development organizations (i.e., no manufacturing), and academic institutions engaged in research.

Duplication of firms across the four sources which had the same contact location were removed. In such cases, the contact person closest to the title of product development was included and the other contacts within the same firm and location were removed. From the combined contact list of 5,000 firms, 1,500 firms were selected at random (without replacement) for the initial mailing. The initial mailing included a personalized cover letter describing the research project, a postage-paid participation form which asked for contact details of the respondent (which also allowed contact person to decline participation) in case the firm agreed to participate, copy of the survey, and a postage-paid return envelop. The cover letter and survey described the ideal respondent and characteristics of the new product development project which qualified for inclusion in the research (see Appendix). Firms were promised an executive summary of the results. Firms which had not developed a new product and/or launched a new product recently were not included in the research project. Similarly, firms which had launched products very recently and had not been in the market for at least one year since launch were excluded. Out of the 1,500 firms contacted, 1,396 could be reached (104 letters were undelivered because of either change of address or because the contact person had left the firm) of which 57 firms indicated in the participation form that they did not wish to participate in the project. Fifteen surveys were returned because the firms had not recently developed or launched a new product. Thus, the effective contact list was for 1,324 firms of which 346 firms responded and returned the survey, constituting a response rate of 26.1%. Of the 346 surveys that were returned, eight surveys could not be used on account of excessive missing data. Therefore, responses from 338 firms (more specifically new product development projects) were used to test the hypotheses in this research.

To detect non-response bias, a test was conducted to see if there were differences between late respondents and early respondents in terms of variables germane to the conceptual model (Armstrong and Overton 1977; Lambert and Harrington, 1990). The sample of respondents was split into two categories, early and late respondents on the basis of date of receipt of the survey. The first 10% from the early respondents group and the last 10% from the late respondents group were selected for carrying out the test. A random sample of eight items was selected from the survey instrument and values for the eight items for respondents in both the groups were compared. The items selected for comparison and the results of the t-test comparing the sample means for each of the eight items across the two groups are shown in Table 4.1. As can be seen from this table, there was no statistical significance between the means for the eight items across the two groups indicating that non-response bias is not a problem in this study.

This chapter began by describing the sampling frame and unit of analysis for this research and then described the methods used to develop and pilot test the survey instrument. Finally, the procedures used for collecting the data were discussed. Chapter V presents the data analysis and findings of this research. In Chapter VI, the findings are synthesized and contributions from this research are identified.

Table 4.1 : Assessment of Non-Response Bias

Description of Item	Category	Mean	t-value	Significance Level
Supplier Integration – Direct Communication with supplier	Early Respondent Late Respondent	6.85 7.03	.319	.751
Design-Manufacturing Integration – Translating customer preferences into process parameters	Early Respondent Late Respondent	4.83 5.56	1.061	.293
Customer Integration – Including customers in decisions concerning manufacturing	Early Respondent Late Respondent	3.53 3.44	.146	.884
Customer Integration – Changing product standards to the benefit of customers	Early Respondent Late Respondent	7.24 7.32	.175	.862
Concurrent Process Management – Information made readily available to manufacturing as product design evolved	Early Respondent Late Respondent	6.18 6.47	.515	.608
Fit with Firm Capabilities (Planning Stage) – Prior experience in designing similar products	Early Respondent Late Respondent	7.91 8.00	.162	.872
Fit with Firm Capabilities (End of Project Stage) – Availability of manufacturing capacity	Early Respondent Late Respondent	7.70 7.96	.496	.622
Fit with Firm Capabilities (End of Project Stage) – Ability to handle major design changes	Early Respondent Late Respondent	7.15 7.41	.475	.636

CHAPTER 5

ANALYSIS AND FINDINGS

The purpose of this chapter is to describe the characteristics of the sample, assess the quality of data using reliability and validity analysis, and report the findings relating to each hypotheses. Findings from hypotheses which were not originally proposed but are logically connected to existing hypotheses are marked as "post-hoc". The synthesis of findings in Chapter VI includes the findings from post-hoc analyses. Consistent with a recent meta analysis of empirical studies in product development projects, which found that researchers focused on two kinds of links -- between practice and performance, and between construct and performance – interchangeably, this research also investigates both types of linkages (see Montoya-Weiss and Calontone, 1994). Thus, both exploratory factor analysis and regression analyses techniques are used in this research.

5.1 Introduction

In this chapter, the frequency distribution of key descriptor variables of the research sample are reported first. This is followed by an analysis of the measurement properties (i.e., reliability analysis and validity analysis) of the constructs germane to the supply chain integration framework. In the final section, the findings relating to each research question are presented. Within each research question, pertinent post-hoc analyses that were carried out are also reported. For example, the overall fit of the conceptual model in Figure 1 was tested using confirmatory factor analysis. Also, the dimensionality of the constructs in Figure 1 was tested using exploratory factor analysis.

It may be noted that there are very few studies that have proposed or tested the dimensionality of the constructs of Figure 1 in previous research. For example, the dimensionality of the three integration mechanisms examined in this research - supplier integration, design-manufacturing integration and customer integration – has not been examined in previous research. Thus, exploratory factor analysis techniques followed by post-hoc confirmatory factor analysis was carried out.

5.2 Description of the Sample

5.2.1. Company Background

The characteristics of the companies in the research sample in terms of age, size (as measured by number of employees) and industry background are reported. The new product projects that comprise the research sample were developed, for the most part, in large and more experienced companies. As can be seen from Table 5.1, 77% of the sample were in business for 14 or more years. Also, approximately half of the sample consisted of firms that had 500 or more employees (see Table 5.2).

Table 5.1. Frequency Distribution of Company Age

Age in Years	Frequency	Percentage
Less than 6	21	6
6 to 14	57	17
more than 14	257	77
TOTAL	335	100

Three cases did not provide valid responses

Table 5.3 lists the industry background for the projects in the sample. As can be seen from this table, a vast majority of the projects were in high tech industries such as electronics, medical instruments, telecommunication equipment and computers. Projects in more mature industries such as automotive, chemicals, machine tools, furniture, metal alloys and food are indicative of industry representation of the rest of the sample.

Table 5.2. Frequency Distribution of Number of Employees

Number of Employees	Frequency	Percentage
Less than 50	36	11
51 to 200	71	21
201 to 500	69	20
501 to 2000	58	17
more than 2000	104	31
TOTAL	338	100

Table 5.3. Frequency Distribution of Industry Background of the Projects

Industry	Frequency	Percentage
Automotive and Automotive Components	34	11
Chemicals	10	3
Computers	15	5
Electronics	140	43
Machine Tools	22	7
Medical Equipment	49	15
Office Equipment	9	3
Telecommunications Equipment	26	8
Others	17	5
TOTAL	322	100

Sixteen cases did not provide valid responses

To summarize, companies in this research sample were typically: in high-value added and short product life cycle types of industries, older companies and large sized companies. However, since the unit of analysis of this research is a new product development project, there could be considerable variation in the project profile within these large companies. After discussing the profile of respondents, the profiles of the project are discussed.

5.2.2. Respondent Profile

In the survey instrument, the ideal respondent was identified as follows:

- a person with overall responsibility for the development project
- a person who was involved in the project from start to end of the project
- a person who interacted with upper management and project personnel for key project decisions

Table 5.4. Frequency Distribution of Respondent's Functional Background

Primary Role	Frequency	Percentage
Program Management	185	55
Design Engineering	70	21
Manufacturing Engineering	24	7
Marketing	15	5
Others	42	12
TOTAL	336	100

Two cases did not provide valid responses

The survey respondents were expected to have leadership responsibility for development projects. Table 5.4 indicates that a majority of respondents (55%) had specific leadership responsibilities relating to product development initiatives. Design engineering was the next highest representative function in the sample. This suggests that design function is extremely important for product development projects in the companies studied. This is not unusual considering that the industry background of a majority of the companies in this sample, i.e., industries with intense competition based on new products with innovative designs. The next highest category is manufacturing engineering functional background. The sample also consisted of respondents with titles (classified as others in Table 5.4) that indicated specific roles in product development or technology development. Representative titles included: Director of Product Development, Chief Technology Officer, Senior Product Development Manager, Development Engineering Manager and Vice-President of Product Development. In a few cases, usually medium sized private companies, the owners or presidents of companies were the respondents.

5.2.3. Project Characteristics

In the survey instrument, guidelines for selecting the new product development project, i.e., the unit of analysis, were identified as follows:

> "Pick a new product development project completed in the last three years for which you were a project manager. By new product we mean any product that is new to your company or division including innovations and new product lines."

One measure of gauging scope of the development project is to measure cumulative person hours worked on the project. As can be seen in Table 5.5, the scope of projects ranged from low (less than 4000 hours) to high (more than 250,000 hours), with an approximately uniform distribution.

Another project characteristic for which data was collected was the location of the new product in the product family stream ranging from incremental changes to new product family platforms. In the new product development literature, the end point of new product family is commonly identified as "really new products". As can be seen from Table 5.6, 91% of the sample comprised of really new products. Very few products in this sample were minor extensions of existing product families.

Table 5.5. Frequency Distribution of Cumulative Person Hours Worked on New Product Development Project (in thousands)

Cumulative Person Hours (in '000)	Frequency	Percentage
1 to 4	49	15
5 to 10	49	15
11 to 30	64	20
31 to 60	41	13
61 to 100	31	10
101 to 250	30	9
more than 250	58	18
TOTAL	322	100

Sixteen cases did not provide valid responses

Table 5.6. Frequency Distribution of Location of Product in its Product Family Stream

Location of this Product in its Product Family Stream	Frequency	Percentage
Superficial Change	1	.3
Minor Extension	20	9
Major Extension	100	31
New Product Family Platform	200	60
TOTAL	331	100

Seven cases did not provide valid responses

Data on the overall cycle times of the new product development project as measured by the duration from product concept to first shipment to the customer were also collected in this research. As shown in Table 5.7, most projects had relatively low cycle times. For 72% of the projects, the cycle times were less than two years. In the extreme, there were a few projects that had very high cycle times (more than five years). Table 5.8 reports the frequency distribution of the duration since product launch. As can be seen from this table, most of the products in the sample were in the market for a duration of less than two years since the launch of the new product.

Table 5.7. Frequency Distribution of New Product Development Project Duration

Duration of New Product Development Project from Product Concept to First Customer Shipment (in months)	Frequency	Percentage
1 to 12	109	32
13 to 24	133	40
25 to 36	63	19
37 to 48	19	6
49 to 60	6	2
more than 60	6	2
TOTAL	336	100

Two cases did not provide valid responses

The final descriptor of project characteristics is the unit sale price of the new product. Table 5.9 shows the frequency distribution of the unit sale price and it is apparent from this table that there is considerable variation in the price levels of each product. It may be noted that for the most part, the unit sale prices reflect initial pricing and not pricing as an adjustment to the long term impact of competitive conditions such as rival offerings, diffusion of product innovation, promotion and so on.

Table 5.8. Frequency Distribution of Duration in Market since Product Launch

Duration of New Product in Market since Launch (in months)	Frequency	Percentage
1 to 12	198	59
13 to 24	84	25
25 to 36	35	11
37 to 48	10	3
more than 48	6	2
TOTAL	333	100

Five cases did not provide valid responses

Table 5.9. Frequency Distribution of Unit Sales Price of Product

Sales Price of A single unit (in US $)	Frequency	Percentage
1 to 101	47	14
11 to 100	61	18
101 to 1000	71	22
1001 to 10000	62	19
10001 to 100000	49	15
100001 to 1000000	28	9
more than 1000000	11	3
TOTAL	329	100

Nine cases did not provide valid responses

In sum, the pattern of project related characteristics of the research sample indicate that most projects had:

- developed and introduced really new products as opposed to incremental products
- low overall cycle times (less than two years)
- products that were introduced in the market relatively recently (less than two years)

On the other hand, the pattern in terms of the scope of projects and unit sales price of the product was less distinctive and had considerable variation across the sample.

5.2.4. Descriptive Statistics of Contingency Variables

Data were also collected on four (contingency) variables - technical complexity of the new product, level of product innovativeness, level of market uncertainty, and stage in the product life cycle for the targeted product – that were pertinent to the research objectives of this dissertation. The frequency distributions for the four contingency variables are reported below. Table 5.10 lists the frequency distribution for technical complexity of the new product. As can be seen from this table, a majority of the new products are technically complex (97% of the sample). Only in 3% of the cases, the level of technical complexity is low.

Table 5.10. Frequency Distribution of Technical Complexity of New Product

Technical Complexity of New Product	Frequency	Percentage
Low	10	3
Moderate	118	35
High	209	62
TOTAL	337	100

One case did not provide valid response

Table 5.11 displays the frequency distribution of the level of innovativeness in the new product. The pattern in this table suggests that the levels of innovativeness range from moderate to high (92% of the sample), with very few of the products being of type which are low in innovativeness (8% of the sample).

Table 5.11. Frequency Distribution of Level of Product Innovativeness for Intended Market

Level of Product Innovativeness for Intended Market	Frequency	Percentage
Low	26	8
Moderate	129	38
High	181	54
TOTAL	336	100

Two cases did not provide valid responses

Table 5.12 shows the distribution of market uncertainty in the research sample. The pattern in this table suggests that most of the products are targeted to markets that are highly uncertain and unstable. A relatively small percentage (24%) of the sample is targeted to stable markets.

Table 5.12. Frequency Distribution of Level of Market Uncertainty

Level of Market Uncertainty	Frequency	Percentage
Low	79	24
Moderate	181	54
High	74	22
TOTAL	334	100

Four cases did not provide valid responses

Finally, Table 5.13. lists the stage in the product life cycle for the new products developed and introduced by the sample respondent firms. The early stages of the product life cycle account for 63% of the sample. This is in part due to the fact that the sample is representative (to a large extent) of high tech industries in which the pressures for innovation are high.

Table 5.13. Frequency Distribution of Stage in the Product Life Cycle for Targeted Product

Stage in Product Life Cycle For Targeted Product	Frequency	Percentage
Introduction	40	12
Early Growth	68	20
Growth	116	35
Early Maturity	51	15
Maturity	56	17
Decline	3	1
TOTAL	334	100

Four cases did not provide valid responses

In sum, the distributions for the four contingency variables suggest that the research sample is comprised of projects in which :

- The technical complexity of the products is high
- The level of market uncertainty is high
- The level of product innovativeness is high
- Most new products are in the early or growth stages of the product life cycle

5.3 Data Quality

5.3.1 Reliability of Scales

Reliability measures the extent to which a measurement scale yields consistent results on repeated replications of the same scale. Assessing the internal consistency of items within a scale is the most important method of establishing reliability when only one form of a measure is available (Flynn, Sakakibara, Schroeder, Bates and Flynn, 1990). The recommended measure for testing the internal consistency of a set of items is provided by Cronbach's coefficient alpha (Churchill, 1979; Cronbach, 1951). An exploratory factor analysis (using principal components and varimax rotation technique) was conducted on all the constructs germane to the conceptual model in Figure 1. For each construct, the factor analysis technique was allowed to specify the number of factors that account for the highest variance explained in the construct. The only specification made was that the eigenvalues for each factor should exceed one. In this section, the results of exploratory factor analysis and reliability analysis are reported. In a later section, confirmatory factor analysis is used primarily to verify discriminant validity of the factors and also as a post-hoc assessment of the overall fit of the model shown in Figure 1. In all there were seven constructs in the conceptual model (see Figure 1). The survey instrument had a total of 63 items representing the seven constructs. The results of exploratory factor analysis are discussed next.

5.3.2. The Supplier Integration Construct

The survey instrument had twenty items relating to supplier integration that were culled out of the literature. From this initial list, eleven items constituting three stable factors emerged (see Table 5. 14). The three stable factors were labeled : Communication and Information Sharing, Design Involvement and Infrastructure. The Communication and Information Sharing factor represented practices that enhanced the frequency of communication and information sharing during the different stages of the development project between the suppliers and the project team. The Design Involvement factor depicted the involvement of suppliers in key design activities such as defining the product architecture and setting design specifications. The Infrastructure factor represented programs and practices with common joint goals and objectives for key suppliers and the firm such as joint training and education programs, access to a common information systems and co-location of project personnel and key suppliers.

Table 5.14. Results of Exploratory Factor Analysis : The Supplier Integration Construct

Items	Factor 1 Communication & Information Sharing	Factor 2 Design Involvement	Factor 3 Infrastructure
Direct communication with key suppliers	**0.81**	0.20	0.20
Frequency of communication with key suppliers in prototype stage	**0.80**	0.27	0.12
Participation of key suppliers in NPD team	**0.71**	0.22	0.23
Frequency of communication with key suppliers in production stage	**0.70**	0.15	0.11
Sharing design knowledge with key suppliers	**0.59**	0.36	0.38
Involvement of key suppliers in defining architecture of new products	0.19	**0.85**	0.16
Involvement of key suppliers in setting design specifications	0.29	**0.80**	0.08
Involvement of key suppliers in product design	0.30	**0.72**	0.27
Common linked information systems	0.20	0.01	**0.74**
Colocation of project personnel and key suppliers	0.12	0.17	**0.73**
Shared education and training programs with key suppliers	0.19	0.33	**0.65**
Eigenvalues	5.01	1.08	1.06
Proportion of Variance Explained	45.50	9.81	9.62
Cumulative Percentage of Variance Explained	45.50	55.31	64.93
Cronbach's alpha for scale	**0.85**	**0.82**	**0.63**

As can be seen from Table 5.14, the scales comprising each of the three factors were internally consistent and the constructs were sufficiently reliable, with Cronbach's alphas ranging from 0.63 to 0.85. Reliability for all three scales exceeded .60, the threshold Nunnally (1978) recommends for exploratory research. There were no significant cross loadings of an item across multiple factors.

5.3.3. The Design-Manufacturing Integration Construct

The survey instrument had seven items relating to design-manufacturing integration that were taken from the literature. From this initial list, only one item which had a low loading was dropped and six items constituting two stable factors were retained (see Table 5. 15). The two stable factors were labeled : Integrative Use of Technology and Design Proactiveness. The Integrative Use of Technology factor measured the extent to which computers were used to link decisions and practices relating to design, production and resource planning. The Design Proactiveness factor represented programs that emphasized early detection of problems such as design for manufacturability (DFM) and translation of customer's preferences into product and process parameters.

Table 5.15. Results of Exploratory Factor Analysis : The Design-Manufacturing Integration Construct

Items	Factor 1 Integrative Use of Technology	Factor 2 Design Proactiveness
Use of Computers to link design and production	**0.85**	0.06
Use of Computers to link design and production planning	**0.83**	0.21
Use of Computers to link design and resource planning	**0.81**	0.13
Translating customer preferences into product parameters	0.00	**0.88**
Translating customer preferences into process parameters	0.12	**0.80**
Design for manufacturability	0.28	**0.48**
Eigenvalues	2.53	1.34
Proportion of Variance Explained	42.13	22.34
Cumulative Percentage of Variance Explained	42.13	62.47
Cronbach's alpha for scale	**0.80**	**0.60**

As can be seen from Table 5.15, the scales comprising both factors were internally consistent and the constructs were sufficiently reliable, with Cronbach's alphas of 0.80 and 0.60. There were no significant cross loadings of an item across multiple factors.

5.3.4. The Customer Integration Construct

The survey instrument had nine items relating to customer integration that were selected from the literature. From this initial list, only one item which had a low loading was dropped and six items constituting two stable factors were retained (see Table 5.16). The two stable factors were labeled : Capturing the Voice of the Customer and Customer Involvement in NPD decisions. The Capturing the Voice of the Customer factor appeared to tap into the group of practices and procedures to gather information on customer needs (i.e., the "voice" of the customer) and transmit these needs in a systematic manner into product specifications or parameters (i.e., the translation process). The second factor of Customer involvement in new product development decisions represented practices that emphasized early involvement of customers in manufacturing and other key decisions in the development process.

The scales comprising both factors were internally consistent and the constructs were sufficiently reliable, with Cronbach's alphas of 0.86 and 0.63 (see Table 5.16). There were no significant cross loadings of an item across multiple factors.

Table 5.16. Results of Exploratory Factor Analysis : The Customer Integration Construct

Items	Factor 1 Capturing "Voice of the Customer"	Factor 2 Customer Involvement in NPD
Reviewing NPD efforts to ensure match with customer needs	**0.83**	0.11
Studying how customers use products	**0.78**	0.05
Sharing Data on customer needs across functions	**0.78**	0.22
Listening to customers needs while developing the product concept	**0.77**	0.36
Meeting with customers	**0.72**	0.33
Including customers in decisions concerning manufacturing	-0.04	**0.81**
Including customers in decisions concerning NPD	0.39	**0.71**
Communicating key aspects of new product to customers	0.30	**0.63**
Eigenvalues	3.97	1.13
Proportion of Variance Explained	49.59	14.09
Cumulative Percentage of Variance Explained	49.59	63.68
Cronbach's alpha for scale	**0.86**	**0.63**

5.3.5. The Concurrent Process Management Construct

In the survey instrument there were nine items relating to concurrent process management that were selected from the literature. From this initial list, two items which had low factor loadings were dropped and the remaining seven items constituting two stable factors were retained (see Table 5.17). The two stable factors were labeled : Dynamic Iterative Routines and Downstream Coordination. The Dynamic Iterative Routines factor represented joint problem solving activities and information sharing on a dynamic basis (i.e., as the different stages of the NPD process evolved). The Downstream Coordination factor captured the coordination of product design activities to downstream steps such as commitments to tooling, production feasibility and manufacturing process costing.

Table 5.17. Results of Exploratory Factor Analysis : The Concurrent Process Management Construct

Items	Factor 1 Dynamic Iterative Routines	Factor 2 Downstream Coordination
Joint problem solving among design, mfg and engg in product design phase	**0.86**	-0.09
Joint problem solving among design, mfg and engg in process design phase	**0.84**	0.15
Information sharing with engg/R&D as process design evolved	**0.80**	0.14
Information sharing with mfg as product design evolved	**0.78**	-0.07
Completeness of product design when mfg made formal cost estimates	-0.04	**0.86**
Completeness of product design when mfg provided feedback on production feasibility	-0.04	**0.81**
Completeness of product design when mfg made purchasing commitments	0.17	**0.75**
Eigenvalues	2.78	1.97
Proportion of Variance Explained	39.64	28.09
Cumulative Percentage of Variance Explained	39.64	67.73
Cronbach's alpha for scale	**0.84**	**0.74**

The scales comprising both factors were internally consistent and the constructs were sufficiently reliable, with Cronbach's alphas of 0.84 and 0.74 (see Table 5.17). There were no significant cross loadings of an item across multiple factors.

5.3.6. The Product Fit with Firm Capability Construct

In the survey instrument there were nine items relating to Product Fit with Firm Capability. All nine items were retained constituting two stable factors which were labeled: Product Fit to Manufacturing Capability and Product Fit to Design Capability (see Table 5.18). The Product Fit to Manufacturing Capability factor represented the fit of the planned new product to firm capabilities in manufacturing such as capacity, flexibility and prior experience. The Product Fit to Design Capability factor captured the Fit of the planned product to design capabilities such as electronic data interchange, computer aided engineering and design familiarity.

Table 5.18. Results of Exploratory Factor Analysis : The Product Fit with Firm Capability Construct

Items	Factor 1 Product Fit to Mfg. Capability	Factor 2 Product Fit to Design Capability
Product fit to the ability to handle changes in production output	**0.92**	0.16
Product fit to the ability to handle changes in product lines	**0.90**	0.17
Product fit to the ability to handle major design changes	**0.90**	0.11
Product fit to available capacity	**0.83**	0.27
Product fit to knowledge of process technology	**0.71**	0.43
Product fit to manufacturing experience	**0.68**	0.42
Product fit to the available expertise in computer aided engineering	0.22	**0.78**
Product fit to the available expertise in electronic data interchange	0.07	**0.77**
Product fit to design experience	0.32	**0.74**
Eigenvalues	5.21	1.29
Proportion of Variance Explained	57.90	14.37
Cumulative Percentage of Variance Explained	57.90	72.27
Cronbach's alpha for scale	**0.93**	**0.70**

The scales comprising both factors were internally consistent and the constructs were sufficiently reliable, with Cronbach's alphas of 0.93 and 0.70 (see Table 5.18). There were no significant cross loadings of an item across multiple factors.

5.3.7. The Product Development Process Performance Construct

In the survey instrument there were four items relating to the Product Development Process Performance Construct. The exploratory factor analysis on these four items yielded one stable factor suggesting that this construct was unidimensional (see Table 5.19). This factor represented the outcome measures of the development process i.e., quality (conformance and design), time-to-market and cost. The scale comprising this factor was sufficiently reliable, with a Cronbach alpha of 0.78 (see Table 5.19).

Table 5.19. Results of Exploratory Factor Analysis : The Product Development Process Performance Construct

Items	Factor 1 Unidimensional
Conformance Quality	n.a.
Design Quality	n.a.
Cost	n.a.
Time-to-Market	n.a.
Cronbach's alpha for scale	**0.78**

Note: n.a. = not applicable

5.3.8. The Product Development Project Success Construct

In the survey instrument there were three items relating to the Product Development Project Success Construct. The exploratory factor analysis on these three items yielded one stable factor suggesting that this construct was unidimensional (see Table 5.20). This factor represented the outcome measures of the new product development project i.e., initial market share, profitability and break-even time. The scale comprising this factor was sufficiently reliable, with a Cronbach alpha of 0.84 (see Table 5.20).

Table 5.20. Results of Exploratory Factor Analysis : The Product Development Project Success Construct

Items	Factor 1 Unidimensional
Initial Market Share	n.a.
Profitability	n.a.
Break even time	n.a.
Cronbach's alpha for scale	**0.84**

Note: n.a. = not applicable

In all the survey instrument contained 63 items that represented the seven constructs. The results from the exploratory factor analysis reduced the original 63 items to a stable and reliable list of 48 items representing the originally proposed seven factors. It must be noted that some of the originally proposed factors turned out to be multidimensional in nature and the refined list of 48 items represented 13 factors and not 7 factors as originally proposed. Taking into account the decrease in number of items (from 63 to 48) and the increase in number of factors (from 7 to 13), the refined list constituted a significant reduction in dimensionality.

5.3.9. Validity of Constructs

The requirements for validity are two fold. The scales must truly measure what it is supposed to measure and it must not measure anything else (Churchill, 1979). To satisfy these two requirements several facets of validity were tested. Content validity measures the extent to which the scale truly measures the concept that it intended to measure, based on the domain of meaning of items comprising the scale (Churchill, 1979). It is a non-statistical assessment of validity which is ensured by expert judgment or through an extended literature search. A high degree of content validity of the scales was ensured by referring to the extant empirical or prescriptive literature relating to each of the scale items followed by confirmation with experienced new product development managers via field interviews.

Convergent Validity

In order to ensure that a set of items reflect a particular construct and is not an artifact of the measurement procedure, it is desirable to include multiple items of the same construct. Convergent validity refers to the extent to which varying approaches to construct measurement yield the same results (Campbell and Fiske, 1959; Churchill, 1979). One method of determining convergent validity is to treat each item in a scale as a different approach to measuring the construct (Ahire, Golhar and Waller, 1996). Convergent validity is assessed by verifying whether each indicator's estimated pattern coefficient on its posited underlying construct factor is significant i.e., greater than twice its standard error (Anderson and Gerbing, 1988). Following this recommendation, a confirmatory factor analysis (CFA) was conducted on the 48 items (comprising 13 factors) as identified in exploratory factor analysis. The confirmatory factor structure was tested using EQS Windows (version 5.6) structural equation modeling software package. Maximum likelihood method of estimation was used. The results are reported in Table 5.21. As can be seen from this table, all factor loadings were statistically significant indicating a high degree of convergent validity.

Discriminant Validity

Discriminant Validity is the extent to which the constituent items of a scale measure only one distinct construct (Churchill, 1979; Bagozzi, Yi, and Phillips, 1991; Ahire et al., 1996). The Lagrange Multiplier (LM) test was used to verify if there was any significant cross loadings of any item on more than one factor. The results as a whole indicated a reasonably high degree of divergence across factors as indicated only a few items that had cross loadings on to a different factor than hypothesized. The fact that all of these factor loadings were not significant as indicated by the multivariate LM test output and that the overall model was significant (as is discussed in the next section) provided reasonable assurance of discriminant validity of the constructs. It may be noted that the factor structure that is being tested in this CFA is post-facto and consequently the fact that a few items had cross loadings in a 48-item 13-factor structure is not unusual. Nevertheless, an assessment of the appropriateness of the proposed factor structure should also include an evaluation of overall fit of the model which is reported next.

The overall validity of the confirmatory factor model was tested using multiple fit criteria. The results of these criteria are reported in Table 5.21. The Chi-squared value for the CFA model is 703.66 for a degree of freedom of 665. This chi-squared value was statistically significant with a p-value of 0.14. Another way of assessing the fit of the overall model is by computing the ratio of Chi-squared to the degree of freedom. According to Matsueda (1982), a ratio of χ^2 to df of no more than four-to-one is considered a good fit. Our value of 1.06 is indicative of a good fit of the model. The EQS output provided two goodness of fit indices - Comparitive Fit Index (CFI) and Bentler-Bonnet Non-Normed Fit Index (BBNFI). Both the fit indices were high (.99 and .99 respectively) indicating a good fit. When these results are considered together, they lend support to the overall validity of the proposed factor structure model.

Table 5.21. Results of Confirmatory Factor Analysis

Construct/ Items	Standardized Loadings	t-values
Supplier Integration – Communication And Information Sharing (F1)		
Participation of key suppliers in NPD team	.71	12.11
Direct communication with key suppliers	.68	11.56
Sharing design knowledge with key suppliers	.80	14.17
Supplier Integration – Design Involvement (F2)		
Involvement of key suppliers in defining architecture of new products	.79	14.76
Involvement of key suppliers in product design	.81	15.13
Involvement of key suppliers in setting design specifications	.74	13.77
Supplier Integration – Infrastructure (F3)		
Shared education and training programs with key suppliers	.72	11.33
Co-location of project personnel and key suppliers	.60	9.49
Design-Manufacturing Integration – Integrative Use of Technology (F4)		
Use of computers to link design and production planning	.79	14.12
Use of computers to link design and production	.74	13.07
Use of computers to link design and resource planning	.71	12.25
Design-Manufacturing – Design Proactiveness (F5)		
Translating customer preferences into product parameters	.81	13.22
Translating customer preferences into process parameters	.62	10.28
Customer Integration – Capturing Voice of The Customer (F6)		
Listening to customers needs while developing the product concept	.86	17.08
Studying how customers use products	.70	12.84
Meeting with customers	.73	13.44
Sharing data on customer needs across functions	.71	13.00
Reviewing NPD efforts to ensure match with customer needs	.71	13.32
Customer Integration – Customer Involvement in NPD decisions (F7)		
Including customers in decisions concerning NPD	.78	12.69
Communicating key aspects of new product to customers	.58	9.68

Table 5.21. Results of Confirmatory Factor Analysis (Cont'd)

Construct/ Items	Standardized Loadings *	t-values
Concurrent Process Management – Dynamic Iterative Routines (F8)		
Information sharing with mfg. as product design evolved	.67	12.36
Information sharing with engg/R&D as process design evolved	.80	14.38
Joint problem solving among design, mfg. and engg. in product design phase	.88	16.94
Joint problem solving among design, mfg. and engg. in process design phase	.81	15.56
Concurrent Process Management – Downstream Coordination (F9)		
Completeness of product design when mfg. gave feedback on prodn. feasibility	.71	12.24
Completeness of product design when mfg. made formal cost estimates	.87	15.00
Completeness of product design when mfg. made purchasing commitments	.62	10.26
Product Fit with Firm Capability – Manufacturing (F10)		
Product fit to knowledge of process technology	.63	11.34
Product fit to available capacity	.70	12.83
Product fit to the ability to handle changes in production output	.85	17.49
Product fit to the ability to handle changes in product lines	.93	19.80
Product fit to the ability to handle major design changes	.84	16.81
Product Fit with Firm Capability – Design (F11)		
Product fit to available expertise in computer aided engineering	.84	12.27
Product fit to available expertise in electronic data interchange	.58	9.04
Product Development Process Performance (F12)		
Conformance Quality	.61	9.89
Design quality	.65	10.92
Cost	.68	11.40
Time-to-market	.72	12.19
Product Development Project Success (F13)		
Market Share	.79	14.12
Profitability	.90	16.28
Break Even Time	.85	15.92

χ^2 Value	703.66
df	665
p-value	0.14
χ^2 to df ratio	1.06
Comparitive Fit Index	.99
Bentler-Bonnett Non-Normed Fit Index	.99

* all factor loadings are significant at $p<.01$ level

Predictive Validity

Predictive or Criterion-related Validity investigates the empirical relationship between the scores on a summated scale (predictor) and an objective outcome (the criterion). The most commonly used measure of predictive validity is a validity coefficient which is the correlation between predictor and criterion scores (Flynn et al., 1990). A validity coefficient is an index of how well criterion scores can be predicted from the scores on the summated scale. In our context, in order to demonstrate predictive validity, all of the exogenous factors constituting the three integration mechanisms and concurrent process management must be correlated with a performance measure such as project success. The results of correlations of the exogenous factors with project success are shown in Table 5.22. With the exception of one factor, all factors were significantly correlated with project success. This validates the inclusion of these exogenous factors in the conceptual scheme that seeks to predict project success.

Table 5.22. Results of Predictive Validity of Constructs : Correlations of Exogenous Factors with Project Success
Pearson Product Moment Coefficients (p-value)

	Criterion Variable
Predictor Variables	**New Product Development Project Success**
Supplier Integration –	
Communication and Information Sharing	.11 (.04)
Design Involvement	.09 (.09)
Infrastructure	.04 (.45)
Design-Manufacturing Integration –	
Integrative Use of Technology	.12 (.03)
Design Proactiveness	.22 (.00)
Customer Integration –	
Capturing "Voice of the Customer	.26 (.00)
Customer Involvement in NPD decisions	.09 (.08)
Concurrent Process Management –	
Dynamic Iterative Routines	.18 (.00)
Downstream Coordination	.12 (.03)

The previous sections demonstrated the desirable measurement properties of the constructs and items in the conceptual model of Figure 1. In the next section, the findings relating to each of the research questions are reported.

5.4 Findings

5.4.1 Antecedents to Project Success

H1: Product Concept Effectiveness and New Product Development Project Success:

Hypothesis 1 proposed a positive relationship between product concept effectiveness and project success. To test this relationship, a regression of the two product fit variables on project success was conducted. The results of the regression analyses of Product fit to manufacturing capability and Product Fit to design capability as independent variables and Project Success as the dependent variable are reported in Table 5.23.

Table 5.23. Results of Stepwise Regression Analysis of the Effect of Product Concept Effectiveness on New Product Development Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: New Product Development Project Success
Product Fit with Manufacturing Capabilities	.19 (3.18)[a]
Product Fit with Design Capabilities	.13 (2.09)[b]
F-Value	14.15[a]
R^2	.08
Adjusted R^2	.07

[a]$p<.01$; [b]$p<.05$

In table 5.23, the F-value, model R^2 and adjusted R^2, standardized regression coefficients of the independent variables and associated t-values are listed. Both indicators of Fit with firm capability were significantly related ($p<.05$) to Project Success. The explanatory power of the model as indicated by model adjusted R^2 was 7%. H1 was supported.

H2 toH4: Development Process Performance and Project Success:

Hypotheses 2 to 5 proposed positive relationships between individual components of development process performance - conformance quality (H2), design quality (H3), time-to-market (H4) and cost (H5) - and project success. To test these relationships, regressions of individual components of development process performance on project success were conducted separately. The results of the regression analyses are shown in Tables 5.24 to 5.27.

As can be seen from tables 5.24 to 5.27, all the four individual components of development process performance - conformance quality, design quality, time-to-market and cost - were significantly related to project success. The explanatory power of the models were between 14 to 20%. H2 to H5 were all supported.

Table 5.24. Results of Regression Analysis of the Effect of Conformance Quality on New Product Development Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable New Product Development Project Success
Conformance Quality	.40 (8.06)[a]
F-Value	64.93[a]
R^2	.16

[a]p<.01

Table 5.25. Results of Regression Analysis of the Effect of Design Quality on New Product Development Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: New Product Development Project Success
Design Quality	.40 (8.02)[a]
F-Value	64.34[a]
R^2	.16

[a]p<.01

Table 5.26. Results of Regression Analysis of the Effect of Time-to-Market on New Product Development Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: New Product Development Project Success
Time-to-Market	.45 (9.21)[a]
F-Value	84.78[a]
R^2	.20

[a]p<.01

Table 5.27. Results of Regression Analysis of the Effect of Cost Performance on New Product Development Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: New Product Development Project Success
Cost Performance	.38 (7.50)[a]
F-Value	56.31[a]
R^2	.14

[a]p<.01

Post-Hoc Analyses: Development Process Performance and Project Success:

In order to further analyze the link between development process performance and project success, several post-hoc analyses were carried out. A stepwise regression analyses of the four components of development process performance was conducted to see the relative importance of each of these components on project success. The results shown in Table 5.28 indicate: (1) all four components are significant predictors ($p<.10$) of project success; and (2) time-to-market appears to be the most significant predictor of all the four components.

In Table 5.29, the results of regressing a composite index of development process performance (simple average of all four components) on project success are shown. The index is a significant predictor of project success and it accounts for 27% of the variation in project success.

Table 5.28. Results of Stepwise Regression Analysis of the Effect of Components of Development Process Performance on New Product Development Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable New Product Development Project Success
Conformance Quality	.15 (2.38)[b]
Design Quality	.11 (1.70)[c]
Time-to-Market	.26 (4.49)[a]
Cost Performance	.15 (2.61)[b]
F-Value	31.99[a]
R^2	.28
Adjusted R^2	.27

[a]$p<.01$; [b]$p<.05$; [c]$p<.10$

Table 5.29. Results of Regression Analysis of the Effect of the Index of Development Process Performance on New Product Development Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: New Product Development Project Success
Index of Development Process Performance	.53 (11.39)[a]
F-Value	129.81[a]
R^2	.28

[a]p<.01

The previous analyses examined the effects of the four components of development process performance and its composite index on the overall construct of project success. In the next analysis, the impact of the four components of development process performance on the individual indicators of project success (i.e., market share, profitability and break even time) is examined. The results are shown in Table 5.30.

As far as market share is concerned, the most important predictor was time-to market followed by design quality. For profitability, cost performance was most important followed by conformance quality and time-to-market. Finally, for break even time, time-to-market was most important followed by conformance quality. All models were significant as indicated by the high F-value. Explanatory power was around 20%. It is interesting to note that different development process measures appear to influence different project success measures.

Table 5.30. Results of Stepwise Regression Analysis of the Effect of Components of Development Process Performance on Components of Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variables: Market Share	Profitability	Break Even Time
Conformance Quality	.12 (1.68)[c]	.17 (3.15)[a]	.18 (3.20)[a]
Design Quality	.19 (2.78)[b]	.07 (1.02)	.04 (.53)
Time-to-Market	.24 (4.27)[a]	.16 (2.75)[b]	.28 (4.77)[a]
Cost Performance	-.02 (-.31)	.30 (5.32)[a]	.13 (2.22)[b]
F-Value	28.54[a]	36.59[a]	31.05[a]
R^2	.21	.25	.22
Adjusted R^2	.20	.24	.21

[a]p<.01; [b]p<.05; [c]p<.10

In order to investigate the possibility of multicollinearity among the four components of development process performance, an analyses of the correlation matrix (see Table 5.31) was done. As expected, the four measures were inter-correlated. It is interesting to note that correlations within similar items in content (conformance and design quality) were higher than the correlations that were dissimilar in content.

Table 5.31. Descriptive Statistics of the Components of Development Process Performance

			Product Moment Correlations		
Variable	**Mean**	**S.D.**	**1**	**2**	**3**
1. Conformance Quality	6.37	2.13	1.00		
2. Design Quality	6.86	1.92	.68[a]	1.00	
3. Cost Performance	5.71	2.37	.38[a]	.45[a]	1.00
4. Time-to-Market	5.11	2.69	.44[a]	.46[a]	.49[a]

[a]p<.01

While the zero order correlations in Table 5.31. suggest that all components are highly inter-correlated, a clearer picture emerges in examining the partial correlations among the four components of development process performance (see Table 5.32). As can be seen from this table, all partial correlations are lower in magnitude as compared to its zero order counter parts. It is also interesting to note that some correlations that were significant in zero order analyses are no longer significant in partial correlational analyses suggesting an investigation as to whether multicollinearity really exists and if so to what extent are the previous results invalid. For this purpose, a partial correlation analyses of the impact of each component (controlled for all other components) on project success, was conducted (see Table 5.33).

Table 5.32. **Partial Correlations of the Components of Development Process Performance**

Variable	Partial Correlations 1	2	3
1. Conformance Quality	1.00		
2. Design Quality	.58[a]	1.00	
3. Cost Performance	.05	.20[a]	1.00
4. Time-to-Market	.15[b]	.17[a]	.34[a]

[a]$p<.01$; [b]$p<.05$; [c]$p<.10$

Recall that in a previous regression analyses of all components on market share (Table 5.30), the most important predictor was time-to market followed by design quality. The same pattern of time-to market followed by design quality is obtained in the partial correlation analysis of the four components on market share (see Table 5.33). The regression analyses results for profitability indicated that cost, conformance quality and time-to-market was the order of importance in terms of strength of effect. In the partial correlation results, cost was followed by time-to-market and then conformance quality. As the difference between the last two in magnitude is not so high, it may be assumed that time and conformance quality are equal in importance after cost performance in terms of their impact on profitability of a new product development project.

Table 5.33. **Partial Correlations between Components of Development Process Performance and Market Share**

Partial Correlations between:		**Controlling For:** Variables
Conformance Quality and Market Share	.11[b]	Design Quality, Cost and Time-to market
Design Quality and Market Share	.14[a]	Conformance Quality, Cost and Time-to market
Cost Performance and Market Share	-.02	Conformance Quality, Design Quality and Time-to market
Time-to-Market and Market Share	.22[a]	Conformance Quality, Design Quality and Cost

[a]$p<.01$; [b]$p<.05$;

Table 5.34. Partial Correlations between Components of Development Process Performance and Profitability

Partial Correlations between:		**Controlling For:** Variables
Conformance Quality and Profitability	.11[b]	Design Quality, Cost and Time-to market
Design Quality and Profitability	.06	Conformance Quality, Cost and Time-to market
Cost Performance and Profitability	.27[a]	Conformance Quality, Design Quality and Time-to market
Time-to-Market and Profitability	.14[a]	Conformance Quality, Design Quality and Cost

[a]$p<.01$; [b]$p<.05$

For break-even time, regression analyses results suggested that time-to-market followed by conformance quality was the order of importance. The partial correlation analysis results confirms the same pattern (see Table 5.35). In sum, the pattern of results in regression and partial correlation analyses are robust enough to discount the threat of multicollinearity among the components of development process performance.

Table 5.35. Partial Correlations between Components of Development Process Performance and Break Even Time

Partial Correlations between:		Controlling For: Variables
Conformance Quality and Break Even Time	$.14^{b}$	Design Quality, Cost and Time-to market
Design Quality and Break Even Time	.02	Conformance Quality, Cost and Time-to market
Cost Performance and Break Even Time	$.11^{b}$	Conformance Quality, Design Quality and Time-to market
Time-to-Market and Break Even Time	$.24^{a}$	Conformance Quality, Design Quality and Cost

$^{a}p<.01$; $^{b}p<.05$;

Post Hoc Analyses: Relative Impact of Product Concept Effectiveness and Development Process Performance on Project Success

It may be recalled that the testing of H1 and H2 to H5, found support for the separate impact of product concept effectiveness and development process performance on project success. A logical extension would be to investigate the relative impact of these two constructs on project success. Accordingly, a stepwise regression analyses of the three constructs - product fit with manufacturing capabilities, product fit with design capabilities and development process performance – on project success was conducted. The results indicate that development process performance and product fit with manufacturing capabilities (and in this order) are significant predictors of project success. The three predictors accounted for 29% of variation in project success. In the next series of post-hoc analyses, interaction terms are also included as predictor variables so as to investigate the possibility that the fit constructs and development process performance might *complement* one another in their joint impact on project success.

Table 5.36. Results of Stepwise Regression Analysis of the Effect of Product Concept Effectiveness and Development Process Performance on New Product Development Project Success Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: New Product Development Project Success
Product Fit with Manufacturing Capabilities	.14 (3.07)[a]
Product Fit with Design Capabilities	.08 (1.58)
Index of Development Process Performance	.50 (10.54)[a]
F-Value	71.27[a]
R^2	.30
Adjusted R^2	.29

[a]p<.01

In Table 5.37, the results of hierarchical regression analyses of product concept effectiveness, development process performance and their interaction terms on the three components of project success are reported. In hierarchical regression, independent variables are entered in a particular order in order to minimize the effect of multicollinearity among the independent variables (Cronbach, 1987, Jaccard, Turrisi and Wan, 1990). First, main effects are entered into the model, following which interaction terms that explain additional variance over and above the main effects enter the model.

An interaction term that enters as a significant independent variable 'over rides' or dominates a significant main effect.

Table 5.37. Results of Hierarchical Regression Analysis of the Effect of Product Concept Effectiveness, Development Process Performance and their Interactions on Components of Project Success
Standardized Coefficients (t-value)

Predictor Variables	Criterion Variables: Market Share	Profitability	Break Even Time
Main Effects:			
Product Fit with Manufacturing Capabilities (PFM)	-.04 (-.25)	.11 (.63)	.07 (1.29)
Product Fit with Design Capabilities (PFD)	.08 (1.43)	.06 (1.17)	-.04 (-.29)
Development Process Performance (DPP)	.17 (2.01)[b]	.35 (4.12)[a]	.34 (4.82)[a]
Interaction Effects:			
PFM X DPP	.32 (3.77)[a]	.17 (1.96)[b]	.13 (1.41)
PFD X DPP	.12 (1.46)	.08 (.96)	.17 (2.44)[b]
F-Value	47.94[a]	53.28[a]	49.91[a]
R^2	.22	.24	.23
Adjusted R^2	.22	.24	.22

[a]p<.01; [b]p<.05; [c]p<.10

In all three regression analyses at least one interaction term enters as a significant predictor. The regression models are all significant with a reasonably high degree of explanatory power (around 22%). For both the market share and profitability regressions, the interaction between product fit with manufacturing capability and development process performance enters as a significant predictor. However, for break even time it is the interaction between product fit with design capability and development process performance that enters as a significant predictor. This result suggests that product concept effectiveness and development process performance have a complementary role in their impact on project success. Also, the performance consequences of this complementary interaction are different depending on the type of project success measure being considered. For near term performance effects such as initial market share and profitability, an emphasis on manufacturing capabilities complements development process performance, while design capability does not. For quick capital recovery, the match of appropriate design skills and good execution appears to have a significant impact.

5.4.2 Antecedents to Product Concept Effectiveness

<u>H6: Supplier Integration and Product Concept Effectiveness:</u> Hypothesis 6 proposed a positive relationship between supplier integration and fit with firm capabilities. To test this relationship, a regression of the three sub-dimensions of supplier integration on the two product fit variables were conducted. The results of the regression analyses of the three dimensions of supplier integration on Product fit to manufacturing capability is shown in the second column of Table 5.38 and the results for Product Fit to design capability is shown in the third column of this table.

Table 5.38. Results of Stepwise Regression Analysis of the Effect of Supplier Integration on Product Concept Effectiveness
Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: Product Fit with Manufacturing Capabilities	Criterion Variable: Product Fit with Design Capabilities
Supplier Integration – Communication and Information Sharing	.08 (1.26)	.02 (.22)
Supplier Integration – Design Involvement	.08 (1.37)	.10 (1.73)[c]
Supplier Integration – Infrastructure	.16 (3.01)[a]	.25 (4.30)[a]
F-Value	9.04[a]	18.13[a]
R^2	.03	.10
Adjusted R^2	.02	.09

[a]p<.01; [b]p<.05; [c]p<.10

The Infrastructure component of supplier integration appeared as a significant predictor of product fit to manufacturing capability as well as product fit to design capability. This suggests that practices such as co-location of project personnel and suppliers, and joint training programs facilitate smoother integration of key suppliers in the product planning effort. These practices improves the planning for the new product by considering suppliers design and manufacturing skills while planning for a new product. The results also show that actual design participation in the NPD project (as indicated by the factor – Design Involvement) is a significant predictor of Product fit with design capability which makes logical sense. H6 was supported.

Although, Supplier Integration - Communication and Information Sharing dimension was expected to influence both dimensions of product fit to firm capabilities, it did not affect either dimension. This is somewhat surprising considering that product planning effectiveness could conceivably be enhanced by improved communication between suppliers and project personnel. Post-hoc analysis of the correlations of the two product fit factors to individual practices constituting the communication and information sharing dimension of supplier integration point to some possibilities for this result. Indeed, the practice of sharing design knowledge with suppliers was significantly correlated to both dimensions of product fit to firm capability ($p<.01$), suggesting that this form of communication enhances planning effectiveness. Similarly, the practices of participation of key suppliers in NPD team and direct communication with key suppliers was significantly correlated to product fit to design capability ($p<.01$). Thus, the relationship that was weak at the construct level, is actually significant at the practice level.

<u>H7: Design-Manufacturing Integration and Product Concept Effectiveness:</u> Hypothesis 7 predicted a positive relationship between design-manufacturing integration and fit with firm capabilities. To test this relationship, a regression of the two sub-dimensions of design-manufacturing integration on the two product fit variables were conducted. The results of the regression analyses for Product fit to manufacturing capability is shown in

the second column of Table 5.39 and for Product Fit to design capability in the third column of this table.

Table 5.39. Results of Stepwise Regression Analysis of the Effect of Design- Manufacturing Integration on Product Concept Effectiveness Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: Product Fit with Manufacturing Capabilities	Criterion Variable: Product Fit with Design Capabilities
Design-Manufacturing Integration – Integrative Use of Technology	.15 (2.72)[a]	.40 (7.98)[a]
Design-Manufacturing Integration – Design Proactiveness	.25 (4.50)[a]	.17 (3.44)[a]
F-Value	19.94[a]	52.22[a]
R^2	.11	.24
Adjusted R^2	.10	.23

[a]$p<.01$

Both components of design-manufacturing integration – Integrative Use of Technology and Design Proactiveness were significant predictors of product fit to manufacturing capability as well as product fit to design capability. This suggests that considering the long term impact of design decisions enhances product planning. Also the use of computers in linking design and manufacturing facilitates product planning. H7 was strongly supported.

<u>H8: Customer Integration and Product Concept Effectiveness:</u> Hypothesis 8 predicted a positive relationship between customer integration and fit with firm capabilities. To test this relationship, a regression of the two sub-dimensions of customer integration on the

two product fit variables were conducted. The results of the regression analyses for Product fit to manufacturing capability is shown in the second column of Table 5.40 and for Product Fit to design capability in the third column of this table.

The results in Table 5.40 show that the factor of customer involvement in key NPD decisions is critical for both types of capabilities - design and manufacturing - but the factor of 'Capturing the Voice of the Customer' is critical only for the design capability. In this research, customer involvement is defined to include consideration of customer needs while making key NPD decisions, thus constituting a generic factor for customer integration. Having a procedure for automatically considering customer needs during the NPD project seems to impact product planning effectiveness. H8 was also supported.

Table 5.40. Results of Stepwise Regression Analysis of the Effect of Customer Integration on Product Concept Effectiveness Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable	
	Product Fit with Manufacturing Capabilities	**Product Fit with Design Capabilities**
Customer Integration – Capturing "Voice of the Customer	.21 (3.87)[a]	.13 (2.16)[a]
Customer Integration – Customer Involvement in NPD decisions	.09 (1.49)	.19 (3.10)[a]
F-Value	15.00[a]	14.22[a]
R^2	.04	.08
Adjusted R^2	.04	.07

[a]$p<.01$

Post Hoc Analyses: Global Test of Impact of Integration Mechanisms on Product Concept Effectiveness

In order to mitigate the artificial inflation of Type II error in testing the hypotheses 6 to 8, a global test with all factors of integration mechanisms as independent variables and product fit to firm capability as dependent variable was carried out. Factor score regression analyses was conducted for this purpose and the results for fit with manufacturing capability and fit with design capability as dependent variables are reported in first and second columns respectively of Table 5.41.

Table 5.41. Results of Factor Score Regression Analyses of the Effects of Supplier, Design-Manufacturing and Customer Integration on Product Concept Effectiveness Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: Product Fit with Manufacturing Capabilities	Criterion Variable: Product Fit with Design Capabilities
Supplier Integration – Communication and Information Sharing	-.05 (-.81)	.07 (1.35)
Supplier Integration – Design Involvement	.00 (0.01)	-.03 (-.55)
Supplier Integration – Infrastructure	-.02 (-.24)	.10 (1.78)[c]
Design-Manufacturing Integration – Integrative Use of Technology	.19 (3.32)[a]	.35 (6.28)[a]
Design-Manufacturing Integration – Design Proactiveness	.13 (2.39)[b]	.17 (3.34)[a]
Customer Integration – Capturing "Voice of the Customer"	.-.05 (-.85)	.04 (.76)
Customer Integration – Customer Involvement in NPD decisions	-.03 (-.54)	-.02 (-.28)
F-Value	8.32[a]	24.02[a]
R^2	.05	.19
Adjusted R^2	.05	.18

[a]$p<.01$; [b]$p<.05$; [c]$p<.10$

The results in Table 5.41 show that both dimensions of design-manufacturing integration are critical for both types of capabilities - design and manufacturing. This suggests that design-manufacturing integration is the most important integration mechanism for enhancing fit with firm capabilities in the areas of design and manufacturing. Also, the infrastructure dimension of supplier integration was a significant predictor of product fit to design capability.

5.4.3 Antecedents to Development Process Performance

<u>H9: Product Concept Effectiveness and Development Process Performance:</u> Hypothesis 9 proposed a positive relationship between fit with firm capabilities and development process performance. To test this relationship, a regression of the two product fit variables on development process performance was conducted. The results of the regression analyses of Product fit to manufacturing capability and Product Fit to design capability as independent variables and Development Process Performance as the dependent variable are reported in Table 5.42.

Table 5.42. Results of Stepwise Regression Analysis of the Effect of Product Concept Effectiveness on the Index of Development Process Performance
Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Index of Development Process Performance
Product Fit with Manufacturing Capabilities	.23 (4.25)[a]
Product Fit with Design Capabilities	.09 (1.44)
F-Value	18.06[a]
R^2	.05
Adjusted R^2	.05

[a]p<.01

The results in Table 5.42 suggest that product planning is a necessary first step for better execution of the development process. In particular, the results point to the criticality of considering the fit of the planned product to existing manufacturing capabilities. H9 was supported. It is interesting to note that product fit to design capabilities did not appear as a significant predictor of development process performance. This does not imply that this factor is unimportant. In fact an examination of the raw correlations of each indicator of product fit to design capability with conformance quality (one of the dimensions of development process performance) revealed significant correlations of all three items at $p<.05$ level. This means that the relationship at the construct-to- construct level was not significant but the relationship at the construct to variable level was significant.

<u>H10: Supplier Integration and Development Process Performance:</u> Hypothesis 10 proposed a positive relationship between supplier integration and development process performance. To test this relationship, a regression of the three sub-dimensions of supplier integration on development process performance was conducted. The results are reported in Table 5.43.

Two of the three dimensions of supplier integration significantly affected development process performance. As per the results, communication and information sharing with key suppliers and infrastructure related practices facilitates proper execution of NPD projects. H10 was supported.

Table 5.43. Results of Stepwise Regression Analysis of the Effect of Supplier Integration on Development Process Performance Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: Index of Development Process Performance
Supplier Integration –	
Communication and Information Sharing	.11(1.67)[c]
Design Involvement	.03 (.35)
Infrastructure	.14 (2.28)[b]
F-Value	8.59[a]
R^2	.05
Adjusted R^2	.04

[a]p<.01; [b]p<.05; [c]p<.10

<u>H11: Design-Manufacturing Integration and Development Process Performance:</u> Hypothesis 11 proposed a positive relationship between design-manufacturing integration and development process performance. To test this relationship, a regression of the two sub-dimensions of design-manufacturing integration on development process performance was conducted. The results are reported in Table 5.44.

Only the Design Proactiveness dimension of design-manufacturing integration appeared as a significant predictor of development process performance. The fact that Integrative use of technology did not appear as a significant predictor is surprising. It is conceivable that this is an artifact of the way this factor was measured. The scale items for this factor measured the extent of use of computers to integrate design, manufacturing and resource planning. It might be that most companies in this sample have already reaped the benefits of these technologies as they might be a "given" in today's manufacturing environment as opposed to a source of advantage. On the whole, H11 was supported.

Table 5.44. Results of Stepwise Regression Analysis of the Effect of Design-Manufacturing Integration on Development Process Performance Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable: Index of Development Process Performance
Design-Manufacturing Integration – Integrative Use of Technology	.05 (.88)
Design Proactiveness	.24 (4.42)[a]
F-Value	19.57[a]
R^2	.06
Adjusted R^2	.05

[a]p<.01

H12: Customer Integration and Development Process Performance: Hypothesis 12 predicted a positive relationship between customer integration and development process performance. To test this relationship, a regression of the two sub-dimensions of customer integration on development process performance was conducted. The results are reported in Table 5.45.

Only the 'Capturing the Voice of the Customer' dimension of customer integration appeared as a significant predictor of development process performance implying that this factor is useful for both product planning and development process execution. Also, the second dimension of Customer Involvement in NPD decisions which was a strong predictor of product planning did not appear to influence development process execution. This suggests the limited role of the customer after major decisions relating to planning have been effectively carried out. H12 was also supported.

Table 5.45. Results of Stepwise Regression Analysis of the Effect of Customer Integration on Development Process Performance Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Index of Development Process Performance
Customer Integration –	
Capturing "Voice of the Customer"	.24 (4.51)[a]
Customer Involvement in NPD decisions	.03 (.50)
F-Value	20.31[a]
R^2	.06
Adjusted R^2	.05

[a]p<.01

H13: Concurrent Process Management and Development Process Performance: Hypothesis 13 predicted a positive relationship between concurrent process management and development process performance. To test this relationship, a regression of the two sub-dimensions of concurrent process management on development process performance was conducted. The results are reported in Table 5.46.

Only the Dynamic Iterative Routines dimension of concurrent process management appeared as a significant predictor of development process performance. The fact that Downstream Coordination did not appear as a significant predictor is surprising. The results suggest that an ongoing real-time upstream and downstream coordination is preferred to static downstream coordination. Also, it is possible that measurement could have played a role on the pattern of this result. This factor largely measured the early 'freezing of design' as a method for effective downstream coordination. It is plausible that other mechanisms for effective downstream coordination may have been practiced by firms which were not captured in this research. This issue is worthy of further exploration. On the other hand, information sharing and joint problem solving which constituted the Dynamic Iterative Routines Factor seems to be effective for enhancing development process execution. H13 was supported.

Table 5.46. Results of Stepwise Regression Analysis of the Effect of Concurrent Process Management on Development Process Performance Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Index of Development Process Performance
Concurrent Process Management – Dynamic Iterative Routines	.27 (5.12)[a]
Downstream Coordination	.07 (1.28)
F-Value	26.20[a]
R^2	.07
Adjusted R^2	.07

[a]p<.01

Post Hoc Analyses: Global Test of Impact of Integration Mechanisms and Concurrent Process Management on Development Process Performance

In order to mitigate the artificial inflation of Type II error in testing the hypotheses 10 to 13, a global test with all factors of integration mechanisms and concurrent process management as independent variables and development process performance as dependent variable was carried out. Factor score regression analyses was conducted for this purpose and the results are reported in Table 5.47.

As can be seen from Table 5.47, Supplier Integration-Infrastructure, Customer Integration-Capturing VOC and Concurrent Process Management - Dynamic Iterative entered as significant predictors of Development Process Performance. It may be noted that design manufacturing integration did not enter as a significant factor, possibly because the impact of such integration is more on up-front activities such as product planning as opposed to downstream activities relating to development process execution. A similar result was found in the case of Concurrent Process Management. While, Dynamic iterative routines was found to have a significant impact on development process performance, downstream coordination did not.

Table 5.47. Results of Factor Score Regression Analyses of the Effects of Integration Mechanisms and Concurrent Process Management on Development Process Performance Standardized Coefficients (t-value)

	Criterion Variable
Predictor Variables	**Development Process Performance**
Supplier Integration – Communication and Information Sharing	.03 (.58)
Supplier Integration – Design Involvement	.09 (1.64)
Supplier Integration – Infrastructure	.11[b] (2.07)
Design-Manufacturing Integration – Integrative Use of Technology	-.01 (-.10)
Design-Manufacturing Integration – Design Proactiveness	.06 (.96)
Customer Integration – Capturing "Voice of the Customer"	.12[b] (2.11)
Customer Integration – Customer Involvement in NPD decisions	.02 (.32)
Concurrent Process Management – Dynamic Iterative Routines	.19[a] (3.24)
Concurrent Process Management – Downstream Coordination	.08 (1.40)
F-Value	9.68[a]
R^2	.09
Adjusted R^2	.08

[a]$p<.01$; [b]$p<.05$; [c]$p<.10$

5.4.4. Contingency Relationships

Four contingency relationships were also tested. The contingencies related to Product Innovativeness, Technical Complexity, Market Uncertainty and Stage in the Product Life Cycle. For all contingency relationships, the dependent variable was time-to-market. For the first three relationships, the independent factor was Concurrent Process Management and for the last relationship, it was Supplier Integration.

H14: Moderating Influence of Product Innovativeness: H14 stated products that were low in innovativeness are more likely to reap the benefits of concurrent process management in terms of lower time to market. In operational terms, this meant that regression slopes for the high and low innovativeness group were statistically and significantly different from one another. Another way of testing this relationship is to include an interaction term along with the main effects of concurrent process management and product innovativeness. H14 will be supported if the interaction term enters as a significant predictor of time-to market.

Tables 5.48 a to c display the results of testing H14. No interaction term entered the equation for both factors of concurrent process management (see Tables 5.48 a and b). However, when a single practice from the factor, i.e., Frequency of Cross functional Communication was considered, the interaction term entered as a significant predictor. H14 was not supported at the construct level, but was supported at the measured variable level.

Table 5.48a. Results of the Moderating Effect of Product Innovation on the Concurrent Process Management (Factor1) -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Concurrent Process Management – Dynamic Iterative Routines	.16 (2.91)[a]
Product Innovation	.00 (.05)
Concurrent Process Management X Product Innovation	.01 (.15)
F-Value	8.45[a]
R^2	.03
Adjusted R^2	.02

[a]p<.01

Table 5.48b. Results of the Moderating Effect of Product Innovation on the Concurrent Process Management (Factor 2) -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Concurrent Process Management – Downstream Coordination	.13 (2.34)[b]
Product Innovation	.02 (.31)
Concurrent Process Management X Product Innovation	.03 (.31)
F-Value	5.48[b]
R^2	.02
Adjusted R^2	.01

[b]p<.05

Table 5.48c. Results of the Moderating Effect of Product Innovation on the Cross Functional Communication -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Cross Functional Communication – Engg./R&D and manufacturing	.05 (0.56)
Product Innovation	-.08 (-1.09)
Cross Functional Communication X Product Innovation	.11 (2.05)[b]
F-Value	4.22[b]
R^2	.01
Adjusted R^2	.01

[b]p<.05

H15: Moderating Influence of Technical Complexity:

H15 stated products that were low in technical complexity are more amenable to the use of concurrent process management to speed up development as measured by time to market. The logic being that prior familiarity with the technical know-how could avoid design lead time delays as in the case of new technologies. Table 5.49 a and b state the results of testing this hypothesis. The second factor of Downstream Coordination did have a differential impact on time-to-market depending on level of technical complexity. Thus, H15 was supported.

Table 5.49a. Results of the Moderating Effect of Technical Complexity on the Concurrent Process Management (Factor 1) -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Concurrent Process Management – Dynamic Iterative Routines	.16 (2.91)[a]
Technical Complexity	-.01 (-.12)
Concurrent Process Management X Technical Complexity	.02 (.19)
F-Value	8.45[a]
R^2	.02
Adjusted R^2	.02

[a]p<.01

Table 5.49b. Results of the Moderating Effect of Technical Complexity on the Concurrent Process Management (Factor 2) -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Concurrent Process Management – Downstream Coordination	.07 (0.72)
Technical Complexity	-.08 (-1.21)
Concurrent Process Management X Technical Complexity	.21 (3.94)[a]
F-Value	15.50[a]
R^2	.04
Adjusted R^2	.04

[a]p<.01

H16: Moderating Influence of Market Uncertainty: While H15 dealt with product characteristics, H16 deals with the characteristics of the target market for the new product. H16 states that products that are targeted to markets that are less uncertain can be speeded up more rapidly using concurrent process management techniques as opposed to products introduced in more uncertain markets. Table 5.50 a and b display the results. As can be seen from these tables, both types of concurrent process management techniques appear to work well for speeding up products targeted to less uncertain markets. H16 was strongly supported.

Table 5.50a. Results of the Moderating Effect of Market Uncertainty on the Concurrent Process Management (Factor1) -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Concurrent Process Management – Dynamic Iterative Routines	.04 (.63)
Market Uncertainty	-.07 (-.70)
Concurrent Process Management X Market Uncertainty	.20 (3.67)[a]
F-Value	13.45[a]
R^2	.04
Adjusted R^2	.04

[a]p<.01

Table 5.50b. Results of the Moderating Effect of Market Uncertainty on the Concurrent Process Management (Factor 2) -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Concurrent Process Management – Downstream Coordination	-.01 (-.07)
Market Uncertainty	-.03 (-.34)
Concurrent Process Management X Market Uncertainty	.21 (3.94)[a]
F-Value	15.50[a]
R^2	.04
Adjusted R^2	.04

[a]p<.01

<u>H17: Moderating Influence of Stage in the Product Life Cycle:</u> The impact of supplier integration on reducing time-to-market goals is a subject of controversy because of inconsistent results. H17 stated that supplier integration facilitates faster time to market only for products that are further along the product life cycle, i.e., mature products. According to this hypothesis, supplier integration has no or less impact for markets in the introduction or growth stage. The results are shown in Tables 5.51 a to c, corresponding to each dimension of supplier integration. As can be seen from these tables, there was no support for this hypothesis. This could be because of the composition of the sample. As shown earlier, the sample was biased towards projects that introduced products that were in the early stage of the product life cycle.

Table 5.51a. Results of the Moderating Effect of Product Life Cycle on the Supplier Integration (Factor1) -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Supplier Integration – Communication and Information Sharing	.14 (2.59)[b]
Product Life Cycle	.06 (1.03)
Supplier Integration X Product Life Cycle	.05 (.92)
F-Value	6.73[b]
R^2	.02
Adjusted R^2	.02

[b]p<.05

Table 5.51b. Results of the Moderating Effect of Product Life Cycle on the Supplier Integration (Factor 2) -Time to Market Relationship Standardized Coefficients (t-value)

Predictor Variables	Criterion Variable Time-to-Market
Supplier Integration – Design Involvement	.14 (2.54)[b]
Product Life Cycle	.06 (1.07)
Supplier Integration X Product Life Cycle	.08 (1.36)
F-Value	6.45[b]
R^2	.02
Adjusted R^2	.02

[b]p<.05

Table 5.51c. Results of the Moderating Effect of Product Life Cycle on the Supplier Integration (Factor 3) -Time to Market Relationship Standardized Coefficients (t-value)

	Criterion Variable
Predictor Variables	**Time-to-Market**
Supplier Integration – Infrastructure	.08 (1.53)
Product Life Cycle	.05 (.98)
Supplier Integration X Product Life Cycle	.06 (.94)
F-Value	2.33*
R^2	.01
Adjusted R^2	.00

*not significant (p>.10)

5.4.5 Summary of Major Findings

The major findings of this research are summarized below:

- All three integration mechanisms examined in this research – supplier integration, design-manufacturing integration and customer integration - were multidimensional in nature. Their measurement properties were tested and found to be robust
- Development Process Performance was an unidimensional construct.
- Conformance Quality was more important than design quality
- The three integration mechanisms had a differential impact on different dimensions of performance
- Components of Development Process Performance had a differential performance impact
- Product Concept Effectiveness and Development Process Performance were complementary in nature

- Performance impact of the complements were different
- Moderating Effect of Product Innovativeness was found
- Moderating Effect of Market Uncertainty was found
- Moderating Effect of Technical Uncertainty was found
- Moderating Effect of PLC was **not** found

This chapter presented the descriptive statistics of the research sample, measurement properties of the different constructs and findings relating to each research question. In the next chapter, a synthesis of the research findings is conducted. Implications from the synthesis to theory building and actionable practice are identified. Limitations of this research are acknowledged and avenues for extensions to this research are offered.

CHAPTER 6

DISCUSSION AND CONCLUSIONS

6.1 Introduction

This dissertation had three research objectives: (1) to understand the relative impact of "product concept effectiveness" and "development process performance" on new product development project success; (2) to understand the relative impact of components of development process performance (time-to-market, cost and quality) on new product development project success; and (3) to identify specific practices that influence product concept effectiveness, development process performance and project success. The results relating to each research objective are first summarized and then synthesized in a subsequent section.

6.2 Determinants of Project Success

The results relating to the first two research objectives are discussed together as they both examine determinants of project success. Both product concept effectiveness and development process performance were found to be significantly related to new product development project success. A more detailed examination revealed that:

- development process performance was more important than product concept effectiveness, although both factors were significant
- within components of product concept effectiveness, product fit to manufacturing capability was critical
- within components of development process performance, time-to-market was consistently the most important predictor

- the interaction of product concept effectiveness and development process performance had a *differential impact* on individual measures of project success
  - for **market share and profitability**, the interaction of product fit to manufacturing capability and development process performance was a significant predictor
  - for **break even time**, the interaction of product fit to *design* capability and development process performance was a significant predictor

6.3. Supply Chain Integration Mechanisms

Research Objective Three related to identifying specific integration mechanisms that influenced product concept effectiveness, development process performance and project success. This objective has a special practical relevance because selecting appropriate sets of antecedent project level practices that affect success in new product development projects is troublesome and many efforts have been known to fail. This research explicated a supply chain framework for grouping similar practices along three types of integration mechanisms in a supply chain - supplier integration, design-manufacturing integration and customer integration. The first and the last type of integration mechanisms represent significant inter-organizational types of coordination that is required for effective management of new product development projects. The second type of integration mechanism is intra-organizational and arguably the most critical type of integration with far-reaching consequences on whether or not the project is a success.

As far as the impact of supply chain integration mechanisms on product concept effectiveness is concerned, the results reveal that all the three types of integration mechanisms that were examined had a significant impact on at least one dimension of product concept effectiveness. Also, the results suggest that product fit to manufacturing capability is influenced by supplier integration (infrastructure dimension), design-manufacturing integration (Design Proactiveness and Integrated Use of Technology dimensions) and customer integration (Capturing Voice of the Customer dimension). Product fit to design capability was also influenced by supplier integration (communication and information sharing, and design involvement dimensions), design-manufacturing integration (Design Proactiveness and Integrated Use of Technology dimensions) and customer integration (Capturing Voice of the Customer and Customer Involvement in NPD decisions dimensions).

Supply chain integration mechanisms and concurrent process management also had a significant impact on development process performance. The results imply that development process performance is influenced by supplier integration (communication and information sharing, and infrastructure dimensions), design-manufacturing integration (design proactiveness dimension) and customer integration (Capturing Voice of the Customer dimension).

6.4 Contingency Relationships

Support for the four contingency relationships tested were mixed. Technical and Market Complexity moderated the influence of concurrent process management on time-to-market as predicted. There was no support for the moderating influence of product innovativeness on the concurrent process management → time to market relationship at the construct level. However, a practice within the concurrent process management factor (frequency of cross functional communication) was found to have a significant moderating influence on the concurrent process management ➔ time to market relationship. Also, there was no support for the moderating influence of stage in the product life cycle on the supplier integration ➔ time to market relationship.

6.5 Synthesis

The three measures of project success - market share, profitability and break even time could be construed as three different (but not necessarily mutually exclusive) 'dials' for monitoring performance of new product development projects. The 'strategic levers' that are required to influence these three measures may be different. Accordingly, it is beneficial to synthesize the results with respect to the influence on these three aspects of project success.

A strong emphasis on the performance measure of market share at the project level is consistent with a market pioneering (called "MP" for brevity) strategy which seeks to penetrate the new market by capturing a high market share by capitulating on the fact that there is an unmet need that can be fulfilled through the new product. The pioneering effect is not long lasting and may be as small as a couple of months in the case of product with low life cycles such as electronics. A strong emphasis on profitability is indicative of an efficiency and effectiveness strategy (called "EE" for brevity) in which projects vie with one another in a portfolio such that profitable projects are retained and less profitable ones are weeded out. This takes place on a dynamic basis via the "go, no-go" decision. Underlying each decision to pursue or abandon a project are questions relating to efficient use of scarce resources and effective choice of products and/or markets.

While the prevalence of EE strategy has precedence, the enabling factors that constitute this strategy is not well understood. In an empirical context, the findings from this dissertation seeks to contribute to this understanding. The last indicator of break even time is pursued in contexts in which huge investments belie individual development projects. The strategy to be used in this case called "window of opportunity" (or WOU) seeks to reduce the time window in which investments are recouped. Both pricing related practices (such as penetration pricing) and timing related practices (reengineering the product delivery process) might be deployed in the WOU strategy. All the three strategies listed above - MP, EE and WOU are not meant to be mutually exclusive. However, the issue of recommending an unqualified selection of one or more of these strategies under varying contexts is beyond the scope of this study.

In Table 6.1, the findings relating to the influence of components of product concept effectiveness on market share, profitability and break even time are displayed. Very Strong effects ($p<.01$) are marked as "✓✓✓", moderately strong effects ($p<.05$) are marked as "✓✓", and strong effects are marked as "✓".

Table 6.1. Strength of Effects for the Product Fit to Capability Components to Project Success Relationships

Item (IV)	Market Share (DV1)	Profitability (DV2)	Break Even Time (DV3)
Fit-Mfg	√√	√√	√√
Fit-Des	√	√	√

As can be seen from the above table, product fit to manufacturing capability had a moderately strong but consistent impact on all three components of project success, suggesting that ensuring manufacturing capability at the time of product planning is a viable strategy to be used for influencing all the three measures. The desired capability are in the following areas: knowledge of process technology, availability of capacity, experience of manufacturing similar products, ability to handle changes relating to volume, mix and design. The effect of product fit to design capability on components of project success is also consistent, albeit, not as strong as the product fit to manufacturing capability. The results appear to imply that an emphasis on planning with manufacturability issues in mind has performance implications relating to MP, EE and MOU strategies.

In Table 6.2, the findings relating to the influence of components of development process performance on market share, profitability and break even time are shown. As can be seen from this table, using time-to market as a measure of quality of execution of a development process is invaluable in terms of its eventual impact on project success. Practices that enhance time-to-market performance appear to be effective across the board whether the intention is market penetration, pioneering or efficiency and effectiveness.

Table 6.2. Strength of Effects for Development Process Performance to Components of Project Success Relationships

Item (IV)	Market Share (DV1)	Profitability (DV2)	Break Even Time (DV3)
Conformance quality	√	√√	√√
Design Quality	√√		
Product Cost		√√√	√√
Time to market	√√√	√√	√√√

Conformance quality also appears to be a consistent and significant predictor of all three measures of project success suggesting that conformance quality is an order qualifier for excelling in new product development projects. But projects win orders primarily through aggressive achievement of time-to market goals. The impact of lowering time to market appears to be on not only improving project success but also on improving other dimensions of development process performance such as conformance quality. This is also evident form the fact that a factor analysis on the four items of development process performance revealed unidimensionality.

The fact that market share and break even time had the same influence factor with the strongest effect, i.e., time-to market implies that this measure is effective to monitor in products that compete on a MP or WOU strategy. A further refinement of these strategies to include an EE strategy requires an emphasis of lowering unit product costs.

In Table 6.3, the findings relating to the influence of integration mechanisms on product concept effectiveness, development process performance and project success are shown. As can be seen from this table, design-manufacturing integration and customer integration are the two key sources of integration mechanisms that impact ultimate project success as well as the mediating constructs of product concept effectiveness, and development process performance. Specifically, the Capturing Voice of the Customer and Design Proactiveness dimensions seem to be the most significant integration mechanisms as far as impact on success is concerned. In other words, the message is that being proactive in design by considering manufacturability issues and also transmitting customer needs related information within the organization is most critical. This is especially interesting because these two dimensions suggest proactiveness as a driving force for success, although one involves inter-organizational communication and the other is intra-organizational communication. The implication of this finding on project structure is that success depends on formal or informal means of tapping into the voice of the customer, Capturing customer needs and being proactive of design commitments at an early stage.

Table 6.3. Strength of Effects for Integration Mechanisms to Components of Product Concept Effectiveness, Development Process Performance and Project Success Relationships

	Fit with Mfg capability	Fit with Design Capability	Development Process Performance	Project Success
Supplier Integration:				
Commn & Info Sharing			√	√
Design Involvement		√		
Infrastructure	√√	√√√	√√	
Design Manufacturing Integration:				
Integrative Use of Technology	√ √	√√√		
Design Proactiveness	√√√	√√	√√√	√√√
Customer Integration:				
Capturing "Voice of the Customer"	√√√	√ √ √	√√√	√√√
Customer involvement in NPD decisions		√√		

In Table 6.4, the findings relating to the influence of concurrent process management on development process performance and project success are shown. As can be seen from this table, the downstream coordination dimension of Concurrent Process Management is the strongest predictor of both project success and development process performance. Once again, the proactiveness dimension appears to have the strongest influence on success. This time, the proactiveness shows up in the form of design freezing at the stage of committing to process choice, tooling and production feasibility considerations.

Table 6.4. Strength of Effects for Concurrent Process Management to Development Process Performance and Project Success Relationships

	Development Process Performance	Project Success
Concurrent Process Management:		
Dynamic Iterative Routines		√√
Downstream Coordination	√√√	√√

In Table 6.5, the findings relating to the influence of integration mechanisms on components of project success are shown. As can be seen from this table, the same two dimensions of design manufacturing and customer integration as in the case of overall construct of project success appear as significant predictors. An additional insight relating to customer integration might be noted. After the dominant factor of Capturing the Voice of the Customer enters, the other factor of Customer Involvement in NPD decisions actually impedes project success. An initial speculation for this result suggests diminishing returns to success after a "distant" data collection and dissemination exercise. This might be due to a rapid change in customer wants over time that might send confusing signals after the initial crystallization of the product concept. Further research is needed to explain this result.

In Table 6.6, the findings relating to the influence of concurrent process management on components of project success are shown. Similar to the earlier situation at the construct level, the dynamic iterative routines dimension is important for all three measures of project success. The downstream coordination dimension of Concurrent Process Management does not seem to be important for market share.

Table 6.5. Strength of Effects for Integration Mechanisms to Components of Project Success Relationships

	Market share	Profitability	Break even time
Supplier Integration: **Commn & Info Sharing** **Design Involvement** **Infrastructure**	√√		
Design Manufacturing Integration: **Integrative Use of Technology** **Design Proactiveness**	√√	√√	√√√
Customer Integration: **Capturing "Voice of the Customer"** **Customer involvement in NPD decisions**	√√√	√ √ √ √√ (-ve)	√√√

Table 6.6. Strength of Effects for Concurrent Process Management to Components of Project Success Relationships

	Market share	Profitability	Break even time
Concurrent Process Management: **Dynamic Iterative Routines** **Downstream Coordination**	√√	√√√ √	√ √ √

6.5.1. Pattern of Influences

The summary of pattern of influences is given in Figure 2. The key findings as can be seen from this figure are:

- Product fit to manufacturing capability was important for all three types of new product development strategies
- Time-to-market was important for market pioneering and for window of opportunity strategies
- Reducing product costs was important for the efficiency and effectiveness strategy

- The integration mechanisms of design-manufacturing (proactive dimension) and customer integration (capturing "voice of the customer" dimension) was the most consistent predictor. They affected two dimensions of development process performance (time and cost) and one dimension of product planning (i.e., fit to manufacturing capability)

- Supplier integration only affected development process performance (both time and cost) not product planning. The infrastructure dimension of supplier integration influenced time-to-market and the design involvement dimension affected product cost

- Concurrent process management not only speeds up time to market, but also reduces product costs. Only the dynamic iterative routines dimension influenced time-to-market, but both the dynamic iterative routines dimension *and* downstream coordination dimension influenced product cost

The implications of this pattern of findings are worth noting. Fit to manufacturing capability appears to be a key consideration in managing NPD projects. This dissertation found that two integrating mechanisms – proactive dimension of design-manufacturing integration and capturing "voice of the customer" dimension of customer integration – could be effective for improving fit to manufacturing capability. Concurrent process management facilitated the reduction in unit costs of the product. However, its impact on time-to-market was less uniform. Only the dynamic iterative routines dimension influenced time-to-market. The role of supplier integration in NPD projects still appears to be controversial. In this dissertation, supplier integration affected development process performance, but not product planning. Moreover, the sub-dimensions of supplier integration had a differential impact on components of development process performance. Supplier involvement in design influenced product costs but not time-to-market.

Investing in infrastructure programs with suppliers appears to affect time-to-market performance.

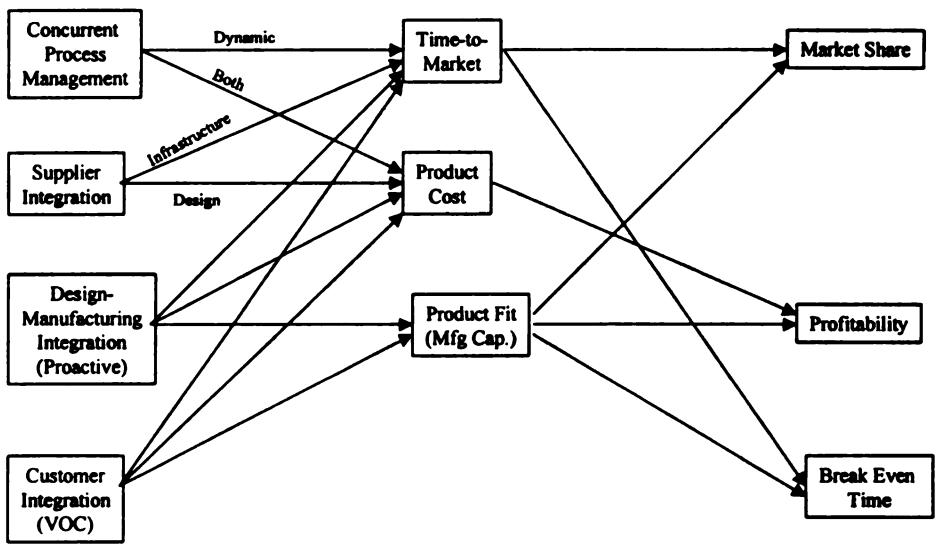

Figure 2 : Pattern of Influences

6.6. Managerial Implications

From a managerial perspective, this research provides product development managers an understanding of specific integration mechanisms that impact mediators of success in new product development projects. In particular, critical supply chain practices that influence product concept effectiveness and development process performance were identified. For example, a manager may be interested in knowing which practices improve conformance quality and time-to-market could benefit from examining customer and design manufacturing integration practices.

At the generic level, this research focused on three common objectives of new product development projects that interest managers, i.e., market share, profitability and break even time. The results from this research offer normative guidelines to managers who are interested in achieving high performance among one or more of these objectives. For example, this research identified "product fit to manufacturing capability of firms" as an essential part of product planning regardless of the type of new product development project objective being pursued. Also, the results of this research show that design manufacturing integration and customer integration are the most crucial integration mechanisms that enhance product fit to manufacturing capability. Specifically, practices within the proactive group of design-manufacturing integration and practices within "capturing the voice of customer' group of customer integration, are most influential in enhancing product fit to manufacturing capability of firms.

The conceptual model can be useful to product development managers entrusted with the audit of the process of product development within their firms. As described in an earlier chapter, previous research on the determinants of project success have failed to capture the integrative role of linking mechanisms as a driver of project success. In fact, this research hypothesized that the impact of such linking mechanisms is via the mediating constructs of product planning and development process execution. This division is of particular interest to NPD managers who are interested in understanding the drivers of the "fuzzy front end" of the development process, as well as the downstream execution of the development process. The results of this research largely supported the conceptual model, thereby offering a new perspective of managing new product development projects. One implication of this result is that a supply chain orientation to managing NPD projects appears to be useful. Although, managing multiple NPD projects simultaneously, which is more reflective of managerial practice, was not explicitly examined in this research, even at the single project level, a supply chain emphasis on integration mechanisms appear to matter. A relatively simple model of supply chain integration, using only three groups of integration, proved to be useful in demonstrating the importance of integration mechanisms in NPD projects.

While the choice of integration mechanisms in a NPD project is an important decision given the limitations of resource commitments, managers are equally interested in the inter-relationships among the different objectives of development process. That is, managers are interested in knowing whether the development process objective of time-to-market can be obtained without sacrificing other objectives such as quality or cost. As discussed in an earlier chapter, this issue is of special interest given the inconsistent findings in the literature. The findings of this study point in favor of the synergy school. Specifically, the message to managers is that achievement of time-to-market objectives has the associative benefits of achieving objective relative to product cost and product quality. Removing "time out of the system" through cycle time reduction techniques appear to have simultaneous impact of lowering product costs and improving design and conformance quality.

Through the results of the contingency relationships investigated in this research, the message to managers is that the impact of concurrent process management on performance is not unequivocal. Specific conditions under which process concurrency might be a viable strategy were identified. For example, this research supported the notion that process concurrency, in general, is more advantageous when deployed in environments that are suggestive of low technical complexity (product factor) or less uncertain markets (market factor).

6.7 Academic Contributions

This research contributes to the literature in several disciplines. To the new product development literature, several insights were found. First, this dissertation took a supply chain view of integration mechanisms and demonstrated its usefulness in the NPD context. Interdepartmental integration has been a focus of many research initiatives. In the product development literature, some researchers have investigated the role of interdepartmental integration as a predictor of success. Hitt, Hoskisson and Nixon (1993) argue that inter-functional integration can positively influence timely new product development if integration mechanisms are managed effectively. However, they do not test this proposition empirically. Empirically, some researchers have found positive relationships between inter-functional integration and NPD performance. For example, Kahn and McDonough (1997) found a direct link between interdepartmental integration and NPD performance. Moenaert, Souder, De Meyer, and Deschoolmeester (1994) examined the interaction between marketing and research and development (R&D) in 40 technologically innovative Belgian companies and found that the quality of the inter-functional climate had a significant effect on project success. This dissertation builds on this work by proposing that supply chain integration positively influence both project success and mediators of project success, i.e., product planning and development process performance.

Second, the conceptual model of this dissertation proposed and tested an integrated schema of constructs from two established streams (rational planning and disciplined problem solving) streams, and found that a new level of analysis merits further investigation, i.e., that of integration mechanisms. This is especially so, considering that the positive impact of several integration mechanisms were consistently shown to impact not only the mediating constructs of product planning and development process performance, but also the ultimate construct of NPD project success. Within integration mechanisms also, several of the underlying practices were common to the third popular stream within NPD research, i.e., the communication web stream. Thus, findings from this dissertation appear to suggest that the three established schools within NPD research actually converge at a higher level of integration mechanisms.

Third, this research demonstrated the differential impact of integration mechanisms on individual measures of product planning and development process performance. For example, supplier integration was found to impact time–to-market and product costs but not product planning effectiveness. On the other hand, design-manufacturing integration and customer integration were found to positively influence both product planning as well as development process execution.

Fourth, this research contributes to the contingency school of NPD research which has been plagued with controversial and inconsistent results. Specifically, concurrent process management was shown to have contingent benefits on time-to-market goals depending on product and market conditions. Support for the limited role of concurrency process management in accelerating NPD projects in less technical, less innovative and less uncertain market was found.

To the business strategy literature, this dissertation makes a contribution by empirically supporting the complementary role of planning and execution at the new product development project level. Prior work in business strategy literature has found the complementary relationship at the project level. For example, Bryson and Bromiley (1993) in an exploratory study of 68 case descriptions of major projects found that a number of contextual variables strongly influenced aspects of the project planning and implementation process and also indirectly influenced project outcomes through the planning and implementation process. In this dissertation, integration mechanisms were found to facilitate the complementary role of planning and execution on NPD project success.

To the operations management literature, this dissertation makes a contribution by empirically supporting the synergy school of thought which argues that superior cost, quality and time performance can be achieved simultaneously. While, the existing literature in operations management have focused on the plant level as the unit of analysis, this dissertation found support for the synergy school at the NPD project level.

Specifically, improvements in time-to-market were associated with improvements in cost and quality performance.

Finally, this dissertation makes contributions to research methods by isolating reliable and valid scales for new constructs (for example, three types of integration mechanisms, and fit to firm capability) at the NPD project level.

6.8 Limitations of the Research

Some limitations of this research are worth noting. This paper addresses the impact of integration mechanisms on a 'static' basis. Hence, the evolution and learning associated with usage of integration mechanisms could not be captured. This would require the use of multiple longitudinal case studies. Also, the impact of integration mechanisms on performance is subject to the confounding of extraneous effects that could not be controlled in this study. Field studies lack the rigor of control for extraneous effects as is possible in lab experiments. This continues to be a pragmatic challenge as the use of lab experiments for studying quality tool usage is prohibitively expensive, especially if one is using objective data from companies.

In this research, we focused on project level (not firm) variables and on firms from several industries. Many other factors can impact new product development project success. The importance of different dimensions of project success itself may vary across and within industries, and practices that positively influence success in one industry may be more or less effective in another. The complexity, hostility, and dynamism of the environment, industry concentration and market dominance can influence all aspects of innovation. For example, the automotive industry context is not as volatile as that of software or electronics, in which product life cycles may be as low as a couple of months. Overall, the results must be interpreted with caution about unwarranted generalizations.

6.9 Directions for Future Research

This research examined the association between integration mechanisms and mediators of project success, their causal relationships is still open to question. A logical extension of this research could consider the causal directions among the constructs. Of particular interest is the integration mechanisms → product concept effectiveness link. In this research, there is an implicit assumption that selection of appropriate integration mechanisms can enhance the effectiveness of planning of the new product. It is conceivable to hypothesize that the causal direction is the reverse, i.e., effective planning helps determine appropriate integration mechanisms. Future research could investigate this possibility.

In this research, cross-sectional research design was used to study the role of integration mechanisms. Future efforts could involve longitudinal research designs that capture the evolutionary pattern of adoption of integration mechanisms. Also, the longitudinal performance impact of integration mechanisms could be captured using dynamic modeling.

This research mainly focused on new product development projects that were managed in North America (US and Canada). Recent research has suggested that the manner in which new product development projects are managed might differ from one country to another (Calantone, Schmidt and Song, 1996; Nakata and Sivakumar, 1996).

While the research cited did not specifically study integration mechanisms, future research could address the issue of whether national culture plays a rôle in the selection and deployment of integration mechanisms. If so, are the performance consequences different from that obtained in this research?

This dissertation was a first step toward generating systematic assessment of the effects of "supply chain" integration mechanisms on new product development project success. Judging from the results of this research, it is clear that future research could identify other sources of integration mechanisms and relate these to project success. For example, technology integration may be an important component of managing new product development projects. Similarly, human resource integration could be another component that can be investigated.

This research opens some interesting new lines of research by shifting the focus from the new product development project level to the level of integration mechanisms. Such a move would constitute a 'finer grain' of analyses in new product development research. In this unit of analysis, the focus is on *how* (and *why*) integration mechanisms affect project success across firms. Similarly, the focus can be shifted at a higher level to the strategic business unit in which multiple products (albeit homogeneous to one another) are developed and introduced simultaneously. It might be that the role of integration mechanisms is more complex in such an environment. Finally, the focus can be shifted to the firm level, i.e., multiple heterogeneous products. While there has been considerable research at the firm level (for a critical review, see Damanpour, 1991), the precise role of integration mechanisms in an environment that includes diverse product and customer markets has not been examined. This could be a fruitful research opportunity to pursue in the future.

APPENDIX A : SURVEY INSTRUMENT

ABOUT THIS SURVEY

This survey is designed to provide new insights into the management of new product development process by assessing the impact of supply chain practices on success in new product development projects(NPD). The survey is being administered nation-wide to firms in multiple industries. The survey asks about project objectives, enabling practices, product concept effectiveness and project success. This research is supported by a Doctoral Dissertation Research Grant from National Association for Purchasing Management (NAPM).

BENEFITS OF PARTICIPATION

A report on the survey findings will be sent exclusively to participants in Summer 1998. The report will help new product development managers to identify

- the relative importance of product concept effectiveness and development process performance in NPD projects
- the relative importance of cost, quality and lead time objectives in NPD projects
- enabling strategies that influence the attainment of cost, quality and lead time objectives
- enabling strategies that strengthen the fit of the planned product to existing firm capabilities
- determinants of overall NPD project success

CONFIDENTIALITY

All responses will be kept confidential. No individual companies, projects, or individuals will be identified. All data will be analyzed and presented on aggregate basis only.

INSTRUCTIONS

1. This survey takes 25 to 30 minutes to complete.
2. This survey asks about a recently completed (in the last 3 years) product development project.

Please select a project where:

- first customer shipment has occurred, and
- the product is of either a manufactured or assembled nature

3. Due to the nature of the questions, for most companies the appropriate person to complete this survey is a person with overall responsibility for the development project. The respondent must have been involved in the project from start to end, and should have interacted with both upper management and project personnel for key project decisions.
4. Please return the survey using the enclosed envelope.
5. If you have any questions regarding this survey, please feel free to call **(517) 353-6381, extn. 275 (Jay)** or e-mail me at **jayaramm@pilot.msu.edu**.

We are committed to providing timely and actionable results.

Thank you for your involvement.

INSTRUCTIONS

- Please answer all the questions.
- If you do not know the answer to any question, or understand the question, mark DK by the question.

SECTION A. PRODUCT DEVELOPMENT PROJECT

Pick a new product development project completed in the last 3 years for which you were a project manager. By new product we mean any product that is new to your company or division. This would also include

- innovations
- new product lines

Name of the product for which you are responding: ______________________________

Description of this product: ______________________________

SECTION B. ENABLING PRACTICES

The following questions ask about the different practices used by your company in supplier integration, design-manufacturing integration, customer integration, and concurrent process management.

INSTRUCTIONS

1. **On a 0 to 10 scale, indicate the extent to which each of the following practices was used by *circling the appropriate number*, and**
2. **In the final column (far right), indicate the effectiveness of the practice to the successful outcome of this specific project. Put a number from 0 to 10 (where 10 = highly effective and 0 = not effective).**

Supplier Integration Practices

	Not Used					Some Extent				Great Extent		Effectiveness Scale 1-10
Participation of key suppliers in NPD team	0	1	2	3	4	5	6	7	8	9	10	___
Direct communication with key suppliers	0	1	2	3	4	5	6	7	8	9	10	___
Shared education & training programs with key suppliers	0	1	2	3	4	5	6	7	8	9	10	___
Common linked information systems(EDI, CAD/CAM, e-mail)	0	1	2	3	4	5	6	7	8	9	10	___
Colocation of project personnel and key suppliers	0	1	2	3	4	5	6	7	8	9	10	___
Sharing design knowledge with key suppliers	0	1	2	3	4	5	6	7	8	9	10	___
Sharing manufacturing knowledge with key suppliers	0	1	2	3	4	5	6	7	8	9	10	___
Sharing customer requirements with key suppliers	0	1	2	3	4	5	6	7	8	9	10	___

Frequency of communication with key suppliers during:

	Seldom					"As Needed"				Very Frequently		Effectiveness Scale 1-10
Concept stage	0	1	2	3	4	5	6	7	8	9	10	___
First prototype stage	0	1	2	3	4	5	6	7	8	9	10	___
Full production stage	0	1	2	3	4	5	6	7	8	9	10	___

Involvement of key suppliers in:

	Not Involved				Some what Involved				Highly Involved			Effectiveness Scale 1-10
Defining the architecture of new products	0	1	2	3	4	5	6	7	8	9	10	___
Setting design specifications	0	1	2	3	4	5	6	7	8	9	10	___
Product design	0	1	2	3	4	5	6	7	8	9	10	___
Prototype building and small scale testing	0	1	2	3	4	5	6	7	8	9	10	___

Extent to which input and suggestions were solicited from key suppliers on:

	Never				Some Extent				Great Extent			Effectiveness Scale 1-10
Design modifications	0	1	2	3	4	5	6	7	8	9	10	___
Problem solving	0	1	2	3	4	5	6	7	8	9	10	___
Reduction in number of parts and critical components	0	1	2	3	4	5	6	7	8	9	10	___

To what extent are the following activities typical of your firm's orientation with its key suppliers :

	Not Typical				Some Extent				Very Typical			Effectiveness Scale 1-10
Our key suppliers assume financial risks in our NPD projects	0	1	2	3	4	5	6	7	8	9	10	___
NPD project goals are agreed upon by our key suppliers prior to start of the project	0	1	2	3	4	5	6	7	8	9	10	___

Design-Manufacturing Integration Practices

To what extent were the following practices used?

	Not Used				Some Extent				Great Extent			Effectiveness Scale 1-10
Design for manufacturability	0	1	2	3	4	5	6	7	8	9	10	___
Job rotation between design and manufacturing personnel	0	1	2	3	4	5	6	7	8	9	10	___
Translating customer preferences into <u>product</u> parameters	0	1	2	3	4	5	6	7	8	9	10	___
Translating customer preferences into <u>process</u> parameters	0	1	2	3	4	5	6	7	8	9	10	___

To what extent were computers or computerized equipment used for linking the following pairs of activities in NPD projects?

	Not Used				Some Extent				Great Extent			Effectiveness Scale 1-10
Design and production planning (i.e., CAD data directly related to CAPP)	0	1	2	3	4	5	6	7	8	9	10	___
Design and production (i.e., CAD data directly controlling production equipment such as CNC machines, robots or FMS)	0	1	2	3	4	5	6	7	8	9	10	___
Design and resource planning (i.e., parts data from CAD directly linked to materials requirement planning (MRP) software)	0	1	2	3	4	5	6	7	8	9	10	___

Customer Integration Practices

To what degree were formal or informal processes used for :

	Not Used					Some Extent				Great Extent		Effectiveness Scale 1-10
including customers in decisions concerning NPD	0	1	2	3	4	5	6	7	8	9	10	___
including customers in decisions concerning manufacturing	0	1	2	3	4	5	6	7	8	9	10	___
communicating key technology aspects of new product to customers	0	1	2	3	4	5	6	7	8	9	10	___
changing product standards to the benefit of customers	0	1	2	3	4	5	6	7	8	9	10	___
listening to customer's needs while developing the product concept	0	1	2	3	4	5	6	7	8	9	10	___
studying how customers use the firm's products	0	1	2	3	4	5	6	7	8	9	10	___
meeting with customers	0	1	2	3	4	5	6	7	8	9	10	___
sharing data on customer needs across functions	0	1	2	3	4	5	6	7	8	9	10	___
reviewing NPD efforts to ensure that they match customer needs	0	1	2	3	4	5	6	7	8	9	10	___

Concurrent Process Management Practices

The following questions address *information sharing, communication and joint problem solving* among design, engineering/R&D, and manufacturing.

To what degree was:	Not at all					Some Extent				Great Extent		Effectiveness Scale 1-10
Information made readily available to manufacturing as the product design evolved?	0	1	2	3	4	5	6	7	8	9	10	___
Information made readily available to engineering/R&D as the process design evolved?	0	1	2	3	4	5	6	7	8	9	10	___
Joint problem solving used in product design phase of the project	0	1	2	3	4	5	6	7	8	9	10	___
Joint problem solving used in process design phase of the project	0	1	2	3	4	5	6	7	8	9	10	___

How complete was the:	0% Complete					50% Complete					100% Complete	Effectiveness Scale 1-10
process design when engineering/R&D ended their active involvement in product design? [A group is actively involved if they are consulted for *key* ensuing NPD project decisions]	0	1	2	3	4	5	6	7	8	9	10	___
product design when manufacturing provided feedback of production feasibility?	0	1	2	3	4	5	6	7	8	9	10	___
product design when manufacturing made formal cost estimates?	0	1	2	3	4	5	6	7	8	9	10	___
product design when manufacturing made commitments to purchase materials, tools and equipment?	0	1	2	3	4	5	6	7	8	9	10	___

	Once a Month (or longer)					Once a Week				Atleast once a day		Effectiveness Scale 1-10
How often did engineering/R&D and manufacturing communicate between themselves?	0	1	2	3	4	5	6	7	8	9	10	___

SECTION C. PRODUCT FIT

The following questions ask about the effectiveness of the new product in terms of matching the capabilities of the firm.

Fit with Firm Capabilities

At the time of project planning, to what extent did the firm have the following skills and resources needed for the targeted product?

	No Expertise					Moderate Expertise					Substantial Expertise
Design											
Computer Aided Engineering	0	1	2	3	4	5	6	7	8	9	10
Electronic Data Interchange	0	1	2	3	4	5	6	7	8	9	10
Prior Experience (of designing similar products)	0	1	2	3	4	5	6	7	8	9	10
Manufacturing											
Knowledge of Process Technology	0	1	2	3	4	5	6	7	8	9	10
Availability of Capacity	0	1	2	3	4	5	6	7	8	9	10
Prior Experience (of manufacturing similar products)	0	1	2	3	4	5	6	7	8	9	10
Volume Flexibility (Ability to handle changes in production output)	0	1	2	3	4	5	6	7	8	9	10
Mix Flexibility (Ability to handle changes in product lines)	0	1	2	3	4	5	6	7	8	9	10
Changeover Flexibility (Ability to handle major design changes)	0	1	2	3	4	5	6	7	8	9	10

At the end of the project, to what extent did the firm **achieve** the originally planned objectives on acquiring the following skills and resources?

	Low Achievement					Moderate Achievement					Excellent Achievement
Design											
Computer Aided Engineering	0	1	2	3	4	5	6	7	8	9	10
Electronic Data Interchange	0	1	2	3	4	5	6	7	8	9	10
Prior Experience (of designing similar products)	0	1	2	3	4	5	6	7	8	9	10
Manufacturing											
Knowledge of Process Technology	0	1	2	3	4	5	6	7	8	9	10
Availability of Capacity	0	1	2	3	4	5	6	7	8	9	10
Prior Experience (of manufacturing similar products)	0	1	2	3	4	5	6	7	8	9	10
Volume Flexibility (Ability to handle changes in production output)	0	1	2	3	4	5	6	7	8	9	10
Mix Flexibility (Ability to handle changes in product lines)	0	1	2	3	4	5	6	7	8	9	10
Changeover Flexibility (Ability to handle major design changes)	0	1	2	3	4	5	6	7	8	9	10

SECTION D. PROJECT OBJECTIVES

The questions below address the achievement of the original objectives of the product development process performance.

Product Development Process Performance

To what extent did the product ...

	Worse				On Target				Exceeded Targets		
Conform to quality objectives set?	0	1	2	3	4	5	6	7	8	9	10
Conform to design objectives set?	0	1	2	3	4	5	6	7	8	9	10
Conform to cost objectives set?	0	1	2	3	4	5	6	7	8	9	10
Conform to time-to-market objectives set?	0	1	2	3	4	5	6	7	8	9	10

SECTION E. PROJECT SUCCESS

The questions below address the overall success of the new product development project.

Product Development Project Success

To what extent was the project successful in terms of ...

	Unsuccessful					Successful					Highly Successful
Initial market share?	0	1	2	3	4	5	6	7	8	9	10
Profitability?	0	1	2	3	4	5	6	7	8	9	10
Break-even time?	0	1	2	3	4	5	6	7	8	9	10

SECTION F. PROJECT CONTEXT

Number of employees in your company (*circle one*): <50 51-200 201-500 501-2000 2000 +

Age of company (*circle one*): <6 years 6-14 yrs. 15 + yrs.

Cumulative person hours worked on this project (in thousands) :

1-4 5-10 11-30 31-60 61-100 101-250 251+

Project duration from product concept to first customer shipment was (*circle one*):

1-12 mos 13-24 mos 25-36 mos 37-48 mos 49-60 mos 61+ mos

The product has been in the market for: (*circle one*):

1-12 mos 13-24 mos 25-36 mos 37-48 mos 49+ mos

The product was targeted for this market (*circle one*):

Consumer Industrial Other ____________________

The approximate price of a single unit in U.S. dollars is (*circle one*):

$1-10 11-100 101-1000 1001-10,000 10,001-100,000 100,001-1,000,000 11,000,000 +

What is the location of this product in its product family stream (*circle one*):

Superficial Change			Minor Extension				Major Extension			New Product Family platform
0	1	2	3	4	5	6	7	8	9	10

With respect to the new product, please rate: (*circle one*):

	Low				Moderate					High	
Technical know-how embodied in the new product	0	1	2	3	4	5	6	7	8	9	10
Innovativeness of product to the intended market	0	1	2	3	4	5	6	7	8	9	10
	Very unstable				Moderately stable					Very Even and stable	
Predictability of market demand	0	1	2	3	4	5	6	7	8	9	10

At what stage of the product life cycle was your main market for the targeted product? (***circle one***):

Introduction **Early Growth** **Growth** **Early Maturity** **Maturity** **Decline**

What was your primary role on this project? (***circle one***):

Design Engineering **Manufacturing Engineering** **Marketing** **Program Management** **Other** ____________

THANK YOU FOR COMPLETING THIS SURVEY.

PLEASE RETURN YOUR COMPLETED QUESTIONNAIRE IN THE ENCLOSED POSTAGE-PAID ENVELOPE

____

____

____

____

To receive the summary report, please attach your business card here or write your address in the space at left.

APPENDIX B: COVER LETTER

<<Date>>

Dear <<Title>> <<Last Name>>:

The Eli Broad Graduate School of Business at Michigan State University, with support from the National Association of Purchasing Management (NAPM) is conducting research with over 5,000 companies nationally regarding **Supply Chain Integration in New Product Development (NPD) Projects.** We would like your firm's participation in this critical benchmarking research beginning in February, 1998.

Launching successful new products continue to be a challenge to most companies. Yet, when done right, new products have a significant impact on a firm's competitiveness through improvements in market share, profitability and overall innovative capability. Through the findings of this research project, we are developing detailed information about:

- Strategies and practices that are most effective to achieve success in NPD projects
- Relative role of cost, quality and time-to-market on NPD project success
- Practices that influence capabilities of firms to develop new products
- Impact of capabilities on NPD project success

In return for your participation, you will receive a benchmarking summary report of your score on supply chain practices relative to the sample of respondents in August 1998. This summary report will provide your firm with valuable strategic and tactical benchmarking information for achieving supply chain integration in NPD projects. All company specific information will be kept strictly confidential, and no companies or individuals will be identified in the research findings.

A survey has been developed which will take approximately 25 to 30 minutes to complete. The appropriate respondent for this survey is the person with overall responsibility for a recently completed new product development project. You are encouraged to involve multiple participants of the NPD project team so that we can provide you with the best and most comprehensive benchmarking information.

We sincerely hope that your firm would participate in this important benchmarking research and believe that the resulting information will be valuable in enhancing your firm's competitiveness. We look forward to your response.

Sincerely,

Jayanth Jayaram	Ram Narasimhan	Roger Calantone
Doctoral Candidate	Professor	Professor and Associate Dean

APPENDIX C: REMINDER POST CARD

<<Date>>

Dear <<Title>> <<Last Name>>:

About 10 days ago, I mailed to you a survey regarding supply chain integration in new product development projects. If you have already responded, thank you very much. If not, is there any chance you could fill it out and mail it now? I would be most grateful. If you need another copy of the survey, please call me at (517) 355-1237 or (517) 353-6381 Ext. 275, and leave your name and address. I will send a copy immediately. Thank you!

Sincerely,

Jayanth Jayaram
Doctoral Candidate - Michigan State University

APPENDIX D: FOLLOW-UP LETTER

<<Date>>

Dear <<Title>> <<Last Name>>:

Recently, I mailed you a survey as part of my dissertation project which I believe will provide insight into the impact of supply chain integration on the success of new product development (NPD) projects. If you have already returned the survey, thank you for your participation. If you have not yet had a chance to complete the survey, could you please take a few minutes and fill out the enclosed survey now? A completed survey from your company is **invaluable** to the success of my dissertation.

In return for your participation, I will provide you with a **customized** report which benchmarks your firm with the sampled firms on detailed information such as:

- Strategies and practices that are most effective to achieve success in NPD projects
- Relative role of cost, quality and time-to-market on NPD project success
- Practices that influence capabilities of firms to develop new products

All company specific information will be kept strictly confidential, and no companies or individuals will be identified in the research findings. To receive the customized report please staple your business card to the completed survey and return in the enclosed stamped envelop. I expect to mail you the customized report no later than August 1998.

The research proposal for this dissertation project won a national award in a competition hosted by National Association of Purchasing Management in 1997. Both the pretest of my dissertation survey and feedback from early respondents indicated that the survey typically took less than 20 minutes to complete and most found it an enjoyable and informative experience. To the best of my knowledge and based on feedback from initial respondents, there are no questions on my survey that require sharing any proprietary information. However, you be the judge of this.

If you have any questions, please e-mail me at jayaramm@pilot.msu.edu or call me at (517) 355-1237 or (517) 353-6381 ext. 275. Again, I believe this study will be useful to you and look forward to your favorable response.

Sincerely,

Jayanth Jayaram
Doctoral Candidate

REFERENCES

Ahire, S.L., Golhar, D.Y., and Waller, M.A. (1996). Developing and validation of TQM implementation constructs. *Decision Sciences*, 27(1), Winter, 23-56.

Ali, A., Krapfel, R., and LaBahn, D. (1995). Product innovativeness and entry strategy: Impact on cycle time and break even time. *Journal of Product Innovation Management, 12*(1 January), 54-69.

Anderson, James C., and Gerbing, David, W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. Psychological Bulletin, 103(3), 411-423.

Andrews, K.R. (1987). *The Concept of Corporate Strategy*. Irwin:Homewood, IL.

Armstrong, J. Scott and Terry S. Overton. (1977). Estimating Nonresponse Bias in Mail Surveys. *Journal of Marketing Research*, 14 (August), 396-402.

Allen, T. J. (1971). Communications, technology transfer, and the role of technical gatekeeper. *R and D Management, 1*, 14-21.

Atuahene-Gima, K. (1995). An exploratory analysis of the impact of market orientation on new product performance: A contingency approach. *Journal of Product Innovation Management,* 12, 275-293.

Bagozzi, R., Yi, Y., and Phillips, L. (1991). Assessing construct validity in organizational research. *Administrative Science Quarterly*, 36, 421-458.

Bobko, P., Karren, R., and Kerkar, S. (1987). Systematic research needs for understanding supervisory-based estimates of SDy in utility analysis. *Organizational Behavior and Human Decision Processes*, 40, 69-95.

Birou, L. M., and Fawcett, S. E. (1994). Supplier involvement in integrated product development: A comparison of US and European practices. *International Journal of Physical Distribution and Logistics Management, 24*(5), 4-14.

Bollen, K. (1989). *Structural Equations with Latent Variables*. New York: John Wiley and Sons.

Bonaccorsi, A., and Lipparini, A. (1994). Strategic Partnerships in New Product Development: An Italian Case Study. *Journal of Product Innovation Management, 11*, 134-145.

Booz, A. a. H., Inc. (1982). *New Product Management for the 1980's.* New York: Booz Allen and Hamilton.

Boyer, K. K., Ward, Peter, Leong, Keong. (1996). Approaches to the factory of the future: An empirical taxonomy. *Journal of Operations Management, 14*, 297-313.

Brannan, B. (1990,). *Why design for assembly? Cost and quality improvements at Motorola.* Paper presented at the Proceedings of the 1990 International Forum on Design for Manufacturing and Assembly, New Port, Rhode Island.

Brown, S. L., and Eisenhardt, K. M. (1995). Product Development: Past Research, Present Findings, and Future Directions. *Academy of Management Review, 20*(2), 343-378.

Bryson, J.M. and Bromiley, P. (1993). Critical factors affecting the planning and implementation of projects. *Strategic Management Journal*, 14(5 July), 319-337.

Calantone, R. J., and di Benedetto, A. (1996). *Performance and Time-to-Market: Accelerating Cycle Time with Cross-Functional Teams* (Working Paper). East Lansing, MI: Michigan State University.

Calantone, R. J., Schmidt, J. B., & Song, M. X. (1996). Controllable factors of new product success: A Cross-National Comparison. *Marketing Science,* 15(4), 341-358.

Campbell, D.T., and Fiske, D.W. (1959). Convergent and discriminant validation by the multitrait-multimethod matrix. Psychological Bulletin, 56(1), 81-105.

Capon, N., and Glazer, R. (1987). Marketing and Technology: A Strategic Coalignment. *Journal of Marketing, 51*(July), 1-14.

Churchill, G.A. (1979). A paradigm for developing better measures of marketing constructs. *Journal of Marketing Research*, 16, February, 64-73.

Clark, K. B. (1989). Project Scope and Project Performance: The effect of parts strategy and supplier involvement on product development. *Management Science, 35*(10 (October)), 1247-1263.

Cohen, M. A., Eliashberg, J., and Ho, T.-H. (1996). New Product Development: The performance and Time-to-Market tradeoff. *Management Science, 42*(2 (February)), 173-186.

Cooper, R. G. (1979). The Dimensions of Industrial New Product Success and Failure. *Journal of Marketing, 43*(3 Summer), 93-103.

Cooper, R. G. (1990). Stage-gate systems: A new tool for managing new products. *Business Horizons*(May-June), 44-54.

Cooper, R. G., and Kleinschmidt, E. J. (1987). New Products : What Separates Winners from Losers ? *Journal of Product Innovation Management, 4*, 169-184.

Cooper, R. G., and Kleinschmidt, E. J. (1994). Determinants of Timeliness in Product Development. *Journal of Product Innovation Management, 11*, 381-396.

Cordero, R. (1991). Managing for Speed to Avoid Product Obsolescence : A Survey of Techniques. *Journal of Product Innovation Management, 8*, 283-294.

Crawford, M. C. (1992). The Hidden Costs of Accelerated Product Development. *Journal of Product Innovation Management, 9*, 188-199.

Cronbach, L.J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 297-334.

Cronbach, L.J. (1987). Statistical tests for moderator variables: Flaws in analysis recently proposed. *Psychological Bulletin*, 102, 414-417.

Cusumano, A. M., and Nobeoka, K. (1992). Strategy, Structure and Performance in Product Development : Observations from the Auto Industry. *Research Policy, 21*, 265-293.

Damanpour, F. (1991). Organizational Innovation: A meta analysis of effects of determinants and moderators. *Academy of Management Journal, 34*(3), 533-590.

Datar, S., Jordan, C., Kekre, S., Rajiv, S., and Srinivasan, K. (1996). New product development structures: The effect of customer overload on post-concept time to market. *Journal of Product Innovation Management, 13*, 325-333.

De Brentani, U. (1989). Success and failures in new industrial services. *Journal of Product Innovation Management, 6*(4), 239-258.

De Meyer, A. and Van Hooland, B. (1990). The contribution of manufacturing to shortening design cycle times. *R&D Management*, 20(3), 229-239.

Duerr, M. G. (1986). *The Commercial Development of New Products*. New York: Conference Board.

Dumaine, B. (1991). Earning more by moving faster. *Fortune*(October 7), 89-90.

Eisenhardt, K. M., and Tabrizi, B., N. (1995). Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry. *Administrative Science Quarterly, 40*, 84-110.

Emmanuelides, A. P. (1991). Determinants of product development time: A framework for analysis. *Academy of Management Best Paper Proceedings*, 342-346.

Ettlie, J. E., and Reza, E. M. (1992). Organizational Integration and Process Innovation. *Academy of Management Journal, 35*(4), 795-827.

Flynn,B.B., Sakakibara, S., Schroeder, R.G., Bates, K.A., and Flynn, J.E., (1990). Empirical research methods in operations management. *Journal of Operations Management*, 9(2), 250-284.

Garvin, D. A. (1987). Competing on the eight dimensions of quality. *Harvard Business Review*(November-December), 101-109.

Gatignon, H., and Xuereb, J.-M. (1997). Strategic orientation of the firm and new product performance. *Journal of Marketing Research, 34*(February), 77-90.

Graves, S. B. (1989). Why costs increase when projects accelerate. *Research Technology Management, 32*(2), 16-18.

Graves, S. B., Carmichael, W. P., Daetz, D., and Wilson, E. (1991). Improving the product development process. *Hewlett Packard Journal, 42*(3 June), 71.

Griffin, A. (1992). Evaluating QFD's use in US firms as a process for developing products. *Journal of Product Innovation Management, 9*, 171-187.

Griffin, A. (1993). Metrics for Measuring Product development Cycle Time. *Journal of Product Innovation Management, 10*, 112-125.

Gupta, A. K., and Wilemon, D. L. (1990). Accelerating the development of technology-based new products. *California Management Review*(Winter), 24-44.

Handfield, R. B. (1994). Effects of Concurrent Engineering on Make-to-Order Products. *IEEE Transactions on Engineering Management, 41*(4 (November)), 384-393.

Handfield, R.B., and S. Ghosh. (1994). Creating a quality culture through organizational change: A case analysis. *Journal of International Marketing*, 2(3), 7-36.

Hartley, J. L., Meredith, J. R., McCutcheon, D., and Kamath, R. R. (1997). Suppliers' contributions to product development: An exploratory survey. *IEEE Transactions on Engineering Management, 44*(3), 258-267.

Hartley, J. L., Zirger, B. J., and Kamath, R. R. (1997). Managing the Buyer-Supplier Interface for On-time Performance in Product Development. *Journal of Operations Management, 15*(1), 57-70.

Hauptman, O., and Hirji, K. K. (1996). The influence of process concurrency on project outcomes in product development: An empirical study of cross-functional teams. *IEEE Transactions on Engineering Management, 43*(2), 153-164.

Hauser, J. R., and Clausing, D. (1988). The House of Quality. *Harvard Business Review*(May-June), 63-73.

Himmerfarb, P. (1992). *Survival of the Fittest: New Product Development During the 90's*. Englewood, NJ: Prentice Hall.

Hise, R. T., O'Neal, L. O., McNeal, J. U., and Parasuraman, A. (1989). The Effect of Product Design Activities on Commercial Levels of New Industrial Products. *Journal of Product Innovation Management, 6*, 43-50.

Hof, R. D. (1992). Suddenly, Hewlett Packard is doing everything right. *Business Week*(March 23), 88-89.

House, C. H., and Price, R. L. (1991). The return map: Tracking product teams. *Harvard Business Review*(January-February), 92-100.

Iansiti, M. (1995). Science-based product development: An empirical study of the mainframe computer industry. *Production and Operations Management Journal, 4*(4 Fall), 335-359.

Imai, K., Ikujiro, N., and Takeuchi, H. (1985). Managing the new product development process: How Japanese companies learn and unlearn. In R. H. Hayes, K. Clark, and A. Lorenz (Eds.), *The Uneasy Alliance:Managing the Productivity-Technology Dilemma* (pp. 337-375). Boston: Harvard Business School Press.

Ittner, C. D., and Larcker, D. F. (1997). Product development cycle time and organizational performance. *Journal of Marketing Research, 34*(February), 522-534.

Jaccard, J.J., Turrisi, R., and Wan, C.K. (1990). Interaction effects in multiple regression. Newbury Park : Sage Publications.

Jaworski, B. J., and Kohli, A. K. (1993). Market Orientation: Antecedents and Consequences. *Journal of Marketing, 57*(July), 53-70.

Kahn, K. B., and McDonough, E.F. (1997) An empirical study of the relationships among co-location, integration, performance, and satisfaction, *Journal of Product Innovation Management*, 14(3, May), 161-178.

Kessler, E. H., and Chakrabarti, A. K. (1996). Innovation speed : A conceptual model of context, antecedents, and outcomes. *Academy of Management Review, 21*(4), 1143-1191.

Kleinschmidt, E. J., and Cooper, R. G. (1991). The impact of product innovativeness on performance. *Journal of Product Innovation Management, 8*, 240-251.

Koufteros, X. (1995). *Time-based competition:Developing a nomological network of constructs and instrument development.* Unpublished Unpublished Ph.D. Dissertation, University of Toledo, Toledo, OH.

Krishnan, V. (1996). Managing the simultaneous execution of coupled phases in concurrent product development. *IEEE Transactions on Engineering Management,* 43(2 May), 210-217.

LaBahn, D. W., and Krapfel, R. (1994). *Early supplier involvement in new product development: A model of the suppliers' perspective* (Research Report 12-1994). University Park, PA: Pennsylvania State University.

Lambert, Douglas M. and Harrington, Thomas C. (1990). Measuring Nonresponse Bias in Customer Service Mail Surveys. *Journal of Business Logistics*, 11 (2), 5-25.

Larson, C. (1988). Team tactics can cut product development costs. *Journal of Business Strategy, 9*(5 September-October), 22-25.

Lewis, G. (1986). Designing to reduce assembly costs. *Plastics Design Forum, 11*(1 January-February), 54-60.

Liker, J. K., Sobek, D. K., Ward, A. C., and Cristiano, J. J. (1996). Involving suppliers in product development in the United States and Japan: Evidence for set-based concurrent engineering. *IEEE Transactions on Engineering Management, 43*(2 May), 165-178.

Lilien, G. L., and Yoon, E. (1989). Determinants of new industrial product performance: A strategic reexamination of the empirical literature. *IEEE Transactions on Engineering Management, 36*(1 (February)), 3-10.

Mansfield, E. (1988). The speed and cost of industrial innovation in Japan and the United States: External and internal technology. *Management Science, 34*(October), 1157-1168.

Matsueda, R.L. (1982). Testing control theory and differential association : A causal modeling approach. *American Sociological Review*, 47, 489-504.

McCall, M.W., and Bobko, P. (1991). Research Methods in the Service of Discovery. In Dunnette & Hough (Eds.) *Handbook of Industrial and Organization Psychology*, Palo Alto, CA: Consulting Psychologists Press.

Millson, M. R., Raj, S. P., and Wilemon, D. (1992). A survey of major approaches for accelerating new product development. *Journal of Product Innovation Management, 9*, 53-69.

Moenaert , R.K., Souder, W.E., De Meyer, A. and Deschoolmeester, D. (1994). R&D - Marketing integration mechanisms, communication flows, and innovation success, *Journal of Product Innovation Management*, 11 (1, January), 31-45.

Montoya-Weiss, M., and Calantone, R. (1994). Determinants of New Product Performance: A review and meta-analysis. *Journal of Product Innovation Management, 11*, 397-417.

Myers, S., and Marquis, D. G. (1969). *Successful industrial innovations*. (Vol. NSF 69-17). Washington DC: National Science Foundation.

Nakata, C., And Sivakumar, K . (1996), National culture and new product development : An integrative review, *Journal of Marketing*, 60 (1, January), 61-72.

Nevens, R., and Whitney, D. (1989). *Concurrent Design of Products and Processes*. New York: McGraw Hill.

Nijssen, E. J., Arbouw, A. R. L., and Commaneur, H. R. (1995). Accelerating new product development: A preliminary empirical test of a hierarchy of implementation. *Journal of Product Innovation Management, 12*, 99-109.

Nunnally, J.C. (1978). *Psychometric Theory*. New York: McGraw-Hill Book Company.

Ragatz, G. L., Handfield, R. L., and Scannell, T. V. (1997). Success factors for integrating suppliers into new product development. *Journal of Product Innovation Management, 14*(3), 190-202.

Raia, E. (1991). Taking time out of product design. *Purchasing, 110*(6 April 4), 36-39.

Rochford, L., and Rudelius, W. (1992). How involving more functional areas within a firm affects the product process. *Journal of Product Innovation Process, 9*, 287-299.

Rosenau, M. D. (1990). *Faster New Product Development: Getting the Right Product to the Market Quickly*. New York: AMACOM.

Rosenau, M. D., Griffin, A., Castellion, G. A., and Anschuetz, N. F. (1996). *The PDMA Handbook of New Product Development*. New York: John Wiley and Sons.

Rosenthal, S. R., and Tatikonda, M. V. (1993). Time management in new product development: Case findings. *Engineering Management Review*(Fall), 13-20.

Ruekert, R.W., (1992). Developing a market orientation: An organizational strategy perspective. *International Journal of Research in Marketing*, 9, 225-245.

Saxenian, A. L. (1991). The origins and dynamics of production networks in Silicon Valley. *Research Policy, 20*, 423-437.

Shrivastava, P., and Souder, W. E. (1987). The strategic management of technological innovations: A review and a model. *Journal of Management Studies, 24*(1 January), 25-41.

Smith, P. G., and Reinersten, D. G. (1991). *Developing Product in Half the Time*. New York: Van Nostrand Reinhold.

Song, M. X., & Parry, M. (1996). *Product innovativeness and New Product Success in Japanese Firms* (Working Paper). E.Lansing, MI: Michigan State University.

Song, M. X., & Montoya-Weiss, M. M. (1995). *A contingency model of the Japanese new product development process: The moderating effect of technological uncertainty* (Working Paper). E.Lansing, MI: Michigan State University.

Sullivan, L. P. (1986). Quality Function Deployment. *Quality Progress, 19*(6 June), 39-50.

Swink, M. L., Sandvik, C. J., and Mabert, V. A. (1996). Customizing concurrent engineering processes: Five case studies. *Journal of Product Innovation Management, 13*, 229-244.

Takeuchi, H., and Nonaka, I. (1986). The new new product development game. *Harvard Business Review, 64*(1), 137-146.

Tatikonda, M. V. (1995). *Technology planning and implementation in product development projects : An empirical study of innovation type, organization and performance*. Unpublished Ph.D. Dissertation, Boston University, Boston.

Teece, D. J. (1988). Capturing value from technological innovation:Integration, strategic planning and licensing decisions. *Interfaces, 18*(3), 46-61.

Teresko, J. (1991). Hewlett-Packard keeps reinventing itself. *Industry Week, 240*(16 August 19), 44-52.

Trygg, L. (1993). Concurrent engineering practices in selected Swedish companies: A Movement or an activity of the few? *Journal of Product Innovation Management, 10*, 403-415.

Ulrich, K., Sartorius, D., Pearson, S., and Jakiela, M. (1993). Including the value of time in design for manufacturing decision making. *Management Science, 39*(4), 429-447.

Urban, G. L., and Hauser, J. R. (1993). *Design and Marketing of New Products*. Englewoods Cliffs, NJ: Prentice-Hall.

Valentino, D., and Christ, W. (1989). Teaming up for market : Cheaper, better, faster. *Management Review, 78*(11 November), 46-49.

von Braun, C.-F. (1990). The acceleration trap. *Sloan Management Review*(Fall), 49-58.

Welter, T. R. (1990). How to build and operate a product design team. *Industry Week*(April 16), 35-58.

Wheelwright, S. C. (1988). Product development and manufacturing set-up. In M. Tushman and W. Moore (Eds.), *Readings in the Management of Innovation* (Vol. 2nd edition, pp. 444-453). Cambridge, MA: Ballinger.

Wheelwright, S. C., and Clark, K. B. (1992). *Revolutionizing Product Development*. New York: Free Press.

Wind, J., Mahajan, V., and Bayless, J. L. (1990). *The role of new product models in supporting and improving the new product development process:Some preliminary results*. Cambridge, MA: The Marketing Science Institute.

Winner, R. I., Pennell, J. P., Bertrand, H. E., and Slusarczuk, M. M. G. (1988). *The Role of Concurrent Engineering in Weapons Systems Acquisition*. (Vol. IDA Report R-338). Alexandra, VI: Institute of Defense Analysis.

Zangwill, W. I. (1993). *Lightning strategies for innovation : How the world's best firms create new products*. New York: Lexington Books.

Zipser, A. (1992). Chipping away at Intel - the super semiconductor maker loses its monopoly. *Barrons, 72*(12 march 23), 16-17.

Zirger, B. J., and Hartley, J. (1994). A conceptual model of product development cycle time. *Journal of Engineering and Technology Management, 11*, 229-251.

Zirger, B. J., and Hartley, J. L. (1996). The effect of acceleration techniques on product development. *IEEE Transactions on Engineering Management, 43*(May), 143-152.