CRITICAL SUCCESS FACTORS IN THE FRONT-END OF HIGH TECHNOLOGY INDUSTRY NEW PRODUCT DEVELOPMENT

by

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A DISSERTATION

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ABSTRACT
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Title: Critical Success Factors in the Front-end of High Technology Industry New Product Development

The objective of this research was to identify and assess the impact of critical success factors in the front-end segment of new product development in a high technology industry. Based on a literature review of new product development success factors and success measures, a conceptual model was proposed. The front-end success factors in the model were new product strategic fit, product definition, project definition, and organizational roles. The success construct was evaluated from both the operational and market-based success perspectives. A survey instrument along the model dimensions was created and validated. The survey was then administered to employees in a high technology global multi-market semiconductor company. Analysis of the data was accomplished using factor analysis, regression, and structural equation modeling. Innovation level was tested as a moderating variable in the model.

The results indicated support for the construct loading on the front-end factors. Through the regression analysis, it was found that product definition and organizational roles had a positive and significant relationship with market-based success. The new product strategic fit and project definition factors were positively related to operational success. The structural equation modeling provided additional evidence of the construct relationships with product definition having the strongest contribution to the front-end factor.

It was found that the innovation level indeed did moderate the operational success. The impact of operational success on market-based success was shown to positively correlate.

The conclusions from the research may assist new product development practitioners to better manage the activity of the front-end segment. Understanding the importance of managing the critical factors of the front-end and the impact on various success dimensions provides managers and teams with a framework to manage the new product development process. Knowing that success is multidimensional and innovation level has an impact, the front-end process can be adjusted for the particular needs of an organization and the type of new product project.

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CHAPTER I

INTRODUCTION AND SIGNIFICANCE

A. Introduction

In large part, the competitive advantage of high technology firms is driven through innovation in new products. The successful introduction of new products depends primarily on the processes used to develop and launch these products to the market. Given the changes in technology, markets, logistics, and technical challenges, firms constantly struggle to find and apply a new-product development (NPD) process that can lead to improved new-product success rates. This is particularly important for high technology companies that are often subjected to limited market window opportunities and short product lifecycles.

To help organizations learn, the process surrounding NPD has been studied extensively in recent decades, covering a wide breadth of topics. Methods to measure new-product success have been explored at the project and the firm level (Griffin and Page, 1996). Measuring success is necessarily based on an understanding of the factors that lead to success (Cooper, 1994). With an objective to define success factors, some of the earlier studies were centered around new-product–introduction cycle time (Smith and Reinertsen, 1991; Griffin, 2002). The drive for cycle time improvement led to a number of phased-based product development methodologies (McGrath, 1996; Cooper, Edgett, et al., 1997). The focus on cycle time was so concentrated that the years from approximately 1985 to 2000 were termed, “the time-to-market generation," (McGrath, 2004). Other studies reported on the importance of collaboration effects among functional organizations within a firm (Griffin and Hauser, 1996; Millson and Wilemon, 2002). Various forms of integration among R&D, the customer, marketing, manufacturing, suppliers, and strategic partnerships, were studied by Sherman, Souder, et al. (2000). Research on collaboration efforts with those outside of the performing organization, such as customers, suppliers, and universities, was also performed (Ragatz, Handfield, et al., 1997; Faems, Looy, et al., 2005). The importance of team learning has long been noted as a critical aspect for product success (Meyers and Wilemon, 1989; Lynn, Reilly, et al., 2000). New-product performance also has been explored from the perspective of organizational learning (Adams, Day, et al., 1998; Paladino, 2007).

Even though the extensive research to date has provided significant insight towards improvement of the new product process, a particular area of the NPD process that has received less attention is the earliest segment, known as the 'front-end.' Within this segment there is still a significant opportunity for learning that can improve the success of new products. When it comes to high technology firms, which spend a significant amount on research and development, having a better understanding of the critical success factors for the front-end can have a significant impact on their sales revenue.

B. New Product Development Success

Given the importance of new products to an organization's revenue stream, continuous improvement to the process of developing successful products is critical to the bottom line. So what exactly is the level of product success and how is it measured? While much has been learned and reported about the product development process, the average success of released-to-market products has remained below 60 percent from the initial studies of the late 1960s until the most recent (i.e., 2003) Product Development Management Association (PDMA) Comparative Performance Assessment Study (CPAS) (Griffin, 1997; Adams, 2004). The low success rate of launched products is a concern, given that "developing successful new products and services is the lifeblood of today's acknowledged industry leaders" (Dorval and Lauer, 2004, p. 269). In investigating the reasons for the low success rate, studies concluded that failed product innovators did not fully understand customer needs, designed products that cannot be repeatedly manufactured, and launched products without regard for the realities of those who will use the product (Dougherty, 1992). Understanding the needs of the customer and the new-product value proposition are critical to achieving a return on the NPD investment (Cristiano, Liker, et al., 2000; Hamilton, 2002). In its 2003 benchmark study, the American Productivity and Quality Center (APQC) reported that new products typically account for 27 percent of a company's sales (Kahn, Castellion, et al., 2005). Thus, a continuous stream of new products is needed to maintain profits, as new products eventually become mature and are discontinued or surpassed.

In the specific case of high technology companies, the success of new products becomes critical for several reasons. A high technology company is characterized by high R&D expenses, high capital and investment risk, demand of science, high creativity, fast diffusion of technological innovations, fast process of devaluation of the applied technologies, and requirement for team work (Zakrzewska-Bielawska, 2010). Based on the up-front expense, the time-critical development, and the typical short market window, a successful NPD process is particularly important for a high technology company to meet the growth goals of its business.

Because the new high technology product landscape is expensive, fast-paced, and marked with uncertainty, the NPD process requires planning, ownership, and continuous effort. Since the management of the NPD process is multifaceted, Cooper and Kleinschmidt (1988, p. 262) stated that, "New-product success is not a matter of doing a few things in a spectacular fashion; rather, it stems from doing *many things* a bit better than the competition (*emphasis original*)." Annacchino (2003) compared the needed NPD effort in an organization to physical exercise for the human condition, and when NPD programs are poorly directed they manifest the weakness by losing financial strength and eventually losing business for the firm.

In today's business environment, firms that continuously learn faster than their competitors and improve their NPD success will gain a clear sustainable competitive advantage (DeGeus, 1988). Learning and finding ways to improve the success rate of new-products begin with an examination of the process used to develop and release new products to the market.

C. New Product Development Model and Metrics

The NPD process is often depicted as a sideways funnel. Figure 1.1 illustrates a general NPD process model. Ideas enter a front-end segment, pass through several development segments, and ultimately are released to market in the launch segment. The front-end is depicted as a funnel to illustrate that typically more ideas exist than can or should be developed.

Within the overall NPD process, the major segments are divided further into what are known as *phases* or *stages*, which may be formal or informal, depending on the process used by a particular organization. Furthermore, the number of phases in each of the segments depends on the NPD process of an organization. In this dissertation, the terms *phase* and *stage* are used interchangeably. Screening criteria may be placed at one or more of the segment or phase transitions. According to the most recent PDMA benchmark survey (Adams, 2004), more than 71 percent of organizations involved in product development use some type of formal, cross-functional NPD process that relies on deliverable review and approval in a phased approach. The reported use of this type of process increased by almost 20 percent since the previous survey (Griffin, 1997). These same studies reported that the average cycle time for NPD decreased from 36 months in 1990 to 24 months in 1995 to 16 months in 2003.

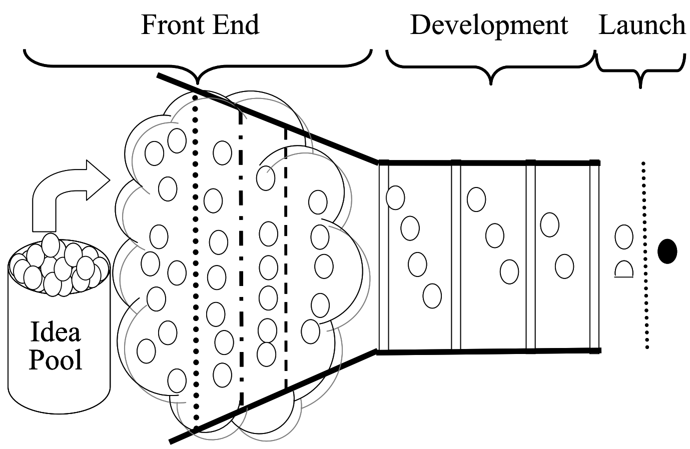

Figure 1.1. Major Segments of a General NPD Model

Research has shown that proficiency in efficiently executing the various NPD activities is associated with improvement in the market performance of new products (Calantone, DiBenedetto, et al., 1993; Song and Parry, 1997). Millson and Wilemon (2002) found that the more effectively a firm performs the development and launch stages of NPD, the more sales it will generate. The findings also showed that the development and launch stages were performed under greater scrutiny than the predevelopment stage.

Unfortunately, the adoption of phase-gate processes and activities have not markedly increased the success average across many types of industries or products enough to be noticeable in the benchmark surveys. It was reported that the gap between "the best" and "the rest" is widening. According to Boike and Adams (2004) the best performers generate 47.6 percent of sales and 49.1 percent in profits from new products – more than twice as much as the rest of the sample. The evidence points to the fact that the best weed out ideas early in the process and then have very high success rates in the later stages. Much of the NPD research stream has centered on understanding the NPD process and success factors to drive up the percent of successful products. However, only a small portion of the prior research has focused specifically on the earliest segment, known as the front-end. It is in this early segment where the best effectively weed out the ideas using a disciplined process approach based on factors that lead to higher success.

D. The Front-End of New Product Development

New products begin as ideas at the start of the front-end segment. Wheelwright and Clark (1992) argued that managing a successful development funnel requires a widening of the mouth as well as a narrowing of the neck. The objective of analyzing more ideas in the front-end is to have a better pool of concepts from which to choose. Approved ideas are then moved to the development segment for detail design, manufacturing or development, and testing. In the development segment, some products fail due to technical, resource, or market reasons, and therefore are not launched in the market.

Yet, even with this knowledge, Cooper and Edgett (1997) reported that the NPD process in many organizations is more like a tunnel than a funnel. In the tunnel model, projects are not screened as they progress from ideas to developed products. Like a tunnel, or a pipeline, a company's NPD has a limited capacity. The filtering is either managed systematically, as Wheelwright and Clark (1992) proposed, or by viewing the organization from a system perspective, where the system has a limited capacity; once the capacity has been exceeded, the system destroys the process (Van-Der-Merwe, 2002). In the case of NPD, this is sometimes viewed as a failure to deal with the information required for proper decision making in the front-end segment. Cooper and Kleinschmidt (1988, p. 262) observed that products that did not achieve financial success, "typically sailed through the front-end and early marketing assessment stages with relatively little time and money spent."

Without a proper front-end process, an organization is either resource-limited, overextended, or using resources on projects that will not provide the best return. Because of this difficulty, by default, product filtering occurs later during a more formalized and expensive product-development phase, resulting in failed products due to technical or market reasons that were not fully explored in an earlier less expensive phase. The lesson was that time and money invested in the early stages will save much aggravation, energy, and wasted resources in the later stages of the projects. This was echoed in the research of Dwyer and Mellor (1991), in which the participants noted that the "up front" predevelopment activities were accomplished with less proficiency than the development activity. The undesired scenario is when the completely designed, developed, tested, and launched product fails in the marketplace because it does not meet the needs of customers or would-be customers.

In contrast, in a well-executed front-end segment, certain product ideas are screened out earlier in the process due to technical feasibility, financial value, or lack of fit with the business strategy. Of the products that are launched, the market is still the ultimate screen and it is not likely that 100 percent of all products will be deemed a success by customers. Nevertheless, striving to raise the average 60 percent launch success baseline is a worthwhile goal.

The front-end segment shown in Figure 1.1 is depicted as a cloud to represent the challenge of making sense of the uncertainty at this stage. This early part of the process – from when the product idea is initiated to the point just prior to the formal development phases – was termed the *fuzzy front-end (FFE)* (Smith and Reinertsen, 1991). The front-end segment was also observed to contain foundational elements such as product and portfolio strategy, NPD organization, structure, roles, incentives, and norms (Khurana and Rosenthal, 1997). Montoya-Weiss and O'Driscoll claimed that the early stages "are referred to as the 'fuzzy front-end' of NPD because they typically involve ill-defined processes and ad hoc decisions" (2000, p. 143). An accepted definition for the FFE is given as follows (Belliveau, Griffin, et al., 2002):

> The Fuzzy Front-end (FFE) is defined as the messy "getting started" period of product development, when the product concept is still very fuzzy. Preceding the more formal product development process, it generally consists of three tasks: strategic planning, concept generation, and, especially, pre-technical evaluation. These activities are often chaotic, unpredictable, and unstructured. In comparison, the subsequent new product development (NPD) process is typically structured, predictable, and formal, with prescribed sets of activities, questions to be answered, and decisions to be made.

Although there was a reported increase between 1995 and 2003 in using more formal processes for the development through launch segments (Tatikonda and Montoya-Weiss, 2001; Adams, 2004), the front-end segment has typically received less attention. Millson and Wilemon (2002) showed that the development and launch stages were performed under greater scrutiny than the predevelopment stage. Spanjol (2003, p. 19) remarked, "the fuzzy front-end is often mentioned in the new product development literature, but very seldom studied."

Researchers agreed that the front-end of the product-development process is an important – if not the most important – segment in the process of developing a new product and that there is a great opportunity for improvement (Smith and Reinertsen, 1991; Khurana and Rosenthal, 1998). Although the FFE was highlighted as the most information-intensive phase of the NPD process, it lacks a formal method to integrate the sources and forms of data into the overall development process (Zahay, Griffin, et al., 2004). Kim and Wilemon (2002a) highlighted that the front-end importance varies according to the product and its market, but few companies realize the competitive advantage a core competence in the management of the front-end can provide in developing new products. There is evidence that the impact of the front-end on product success is understudied and continues to be an area of uncertainty deserving of further research (Reid and de Brentani, 2004). Concerning the earliest NPD segment, the literature discussed the need for a more holistic process-view of the front-end (Khurana and Rosenthal, 1998).

This research aims to shine a light on the process aspects of the front-end in order to arm 'business people' in high technology industries with an improved front-end process through an understanding of the success factors that impact product success. The research and validation of front-end success factors that lead to increased product success may make the early segment process of NPD less fuzzy.

E. Significance of This Research

The research in this dissertation contributes to the new-product development body of knowledge by examining previously reported front-end critical success factors applied to new high technology-industry products in a multimarket high technology company and their corresponding impact on product success. The research is unique in that the reported front-end process critical success factors are evaluated using a multidimensional product-success scale. Specifically, this research focuses on certain product innovations in the categories of new-to-the-company (NTC), improvements (IM), and additions-to-the-existing-product-line (AEL) type of products. The research outcomes in this dissertation have implications for the academic community and NPD management in organizations that work to improve product success.

Potential outcomes are as follows:

- The research provides a framework for the front-end–process critical success factors related to product success.
- A new set of measures is created for future study specifically to research the front-end activity relative to product success.
- For practicing product development managers, the research results in a better understanding of the process for the front-end of new product development.

Chapter II is a review of the literature covering the product lifecycle, the challenges due to the uncertainty of innovation, process models, and success measurement. The factors reported to obtain the holistic front-end are presented. The conceptual model for the research is proposed that relates the factors of the front-end to the impact on product success.

CHAPTER II

LITERATURE REVIEW

A. Introduction

This chapter reviews the elements of the NPD process that have been reported to impact the success of new products. The first section provides the background of the product lifecycle from the front-end to obsolescence. Definitions of uncertainty and innovation are given for the context of the dissertation. The challenges of dealing with ambiguous information during the front-end segment are discussed from the NPD process model perspective.

The chapter then turns to the critical importance of defining and measuring success. The types and levels of product innovations are defined. The success factor literature, with particular emphasis on the front-end, is then covered in detail. The chapter concludes with the proposed conceptual model for the research that relates the critical success factors of the front-end to product success at specified innovation levels.

B. Product Life Cycle: From the Front-end to Obsolescence

A product's life cycle begins with the initial idea and ends when the product is no longer offered for sale and/or supported by the producer. Figure 2.1 extends the product-development funnel model introduced in Chapter 1 through a product's typical life-cycle curve. Following introduction to the market, sales of a product are expected to increase; however with time, sales will decline and the product eventually becomes obsolete. Although the timeline will vary by product, technology, and market environment most products follow the general S-curve model. As products mature and decline, additional new products must continuously enter the development process to sustain a high technology business. Therefore, to remain viable in the marketplace, it is essential for an organization to have a healthy and successful new product introduction process.

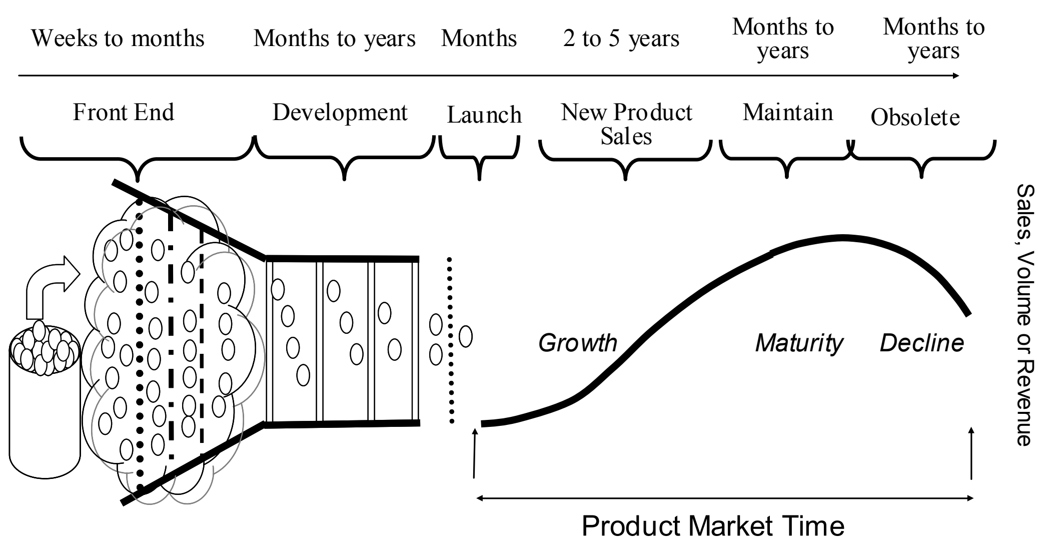

Figure 2.1. Product Development Cycle through Product Life Cycle

[General funnel model after those proposed by Clark and Wheelright (1993) with typical durations (Adams, 2004); followed by the Product Life Cycle S-curve with typical durations (in E. Wilson, Ch. 4, Rosenau, Griffin, et al., 1996).]

The factors that will impact the success of a new product are established long before the new product is released to the marketplace. Decisions made early in the product-development life cycle impact technology choice, features, marketing, development cycle time, manufacturing processes, entry-timing, and market life, all of which affect the product life-cycle cost. This is shown in figure 2.2 where the percent of cost incurred versus the cost committed for a product from concept through production are compared (Dutton, 1998). It was calculated that between 60 and 90 percent of the product life-cycle cost is committed before the ramp-up to full production. Therefore, it is critical to understand which processes and methods will lead to a more successful overall product-development cycle.

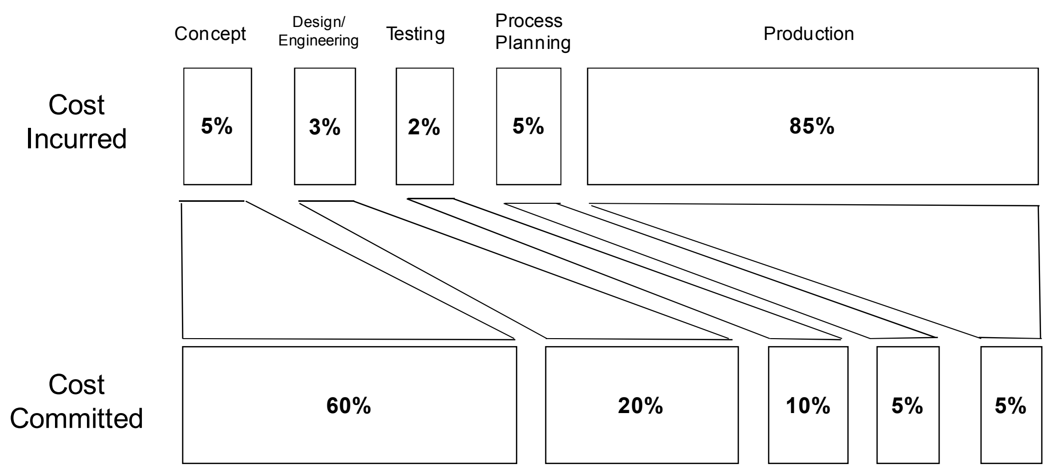

Figure 2.2. Product Life Cycle Cost Incurred Versus Cost Committed

[Reprinted with permission from "Target Setting: Key to Successful NPD Outcomes," John J. Dutton, *PDMA Visions Magazine*, April (1998).]

In an ongoing effort of continuous improvement, the activities prior to the development phases are receiving additional researcher attention due to the belief that the greatest opportunities rest with improving the front-end process (Smith and Reinertsen, 1991; Cooper, 1997; Khurana and Rosenthal, 1997). Without a process and framework to help an organization through the front-end information and uncertainty, the "green light" to proceed to the development segment often is flawed. Although stakeholder influence is highest and the cost of changes are the lowest in the early phases, there often is an urgency to proceed to the development stage before sufficient time is spent on the information of the early phases. Firms must consider carefully the increase in time necessary to deal with the information during the front-end, compared to the cost of developing a product that is unlikely to succeed after significant resources are expended. It is in the early front-end phase where – if left unresolved – ambiguity and uncertainty cause delay and confusion during actual product development (Smith and Reinertsen, 1991). To further understand the ambiguity of the FFE of NPD, the next section defines uncertainty and innovation as it applies to this research.

C. Uncertainty and Innovation in Product Development

Innovation for NPD involves significant uncertainty stemming from the market landscape, the product features, the technology to be used, the suppliers, the manufacturing processes, and (of course) the customer. The definitions from Galbraith (1973) for *uncertainty*, *invention*, and *innovation* are used within the context of this dissertation. Galbraith defined *uncertainty* as the difference between the amount of information required to perform the task and the amount of information already possessed by the organization, *invention* as the creation of a new idea, and *innovation* as the process of applying the invention to create a new process or product. As the innovation level increases, so does uncertainty. How an organization deals with the uncertainty was described in the information-processing literature (Galbraith, 1977; Choo, 1991; Souder and Moenaert, 1992). To manage the uncertainty of innovation, it has been acknowledged that organic approaches to information-processing are necessary (Tatikonda and Montoya-Weiss, 2001). The approach to deal with the information depends on the individuals, the teams, and the organizational processes of NPD.

Recognizing that the processes for developing new products are complex, it is also acknowledged that individuals and groups are subject to limitations. Simon (1957) noted that due to the cognitive limitations of individuals and groups, they create a simplified model of the complex world based on partial information, and they *satisfice* by looking for a course of action that is "good enough" rather than the best possible. The NPD literature reported that teams focused on easily understood information where they could apply their own functionally oriented goals (Adams, Day, et al., 1998). The researchers suggested that increased success is possible if development teams find ways to address ambiguity and overcome compartmentalized thinking.

The view presented by Tatikonda and Montoya-Weiss (2001) was that organizations continue to maintain a myopic, discipline-oriented perspective of the innovation process and outcomes, lacking a collaborative cross-discipline approach. Such an approach may stem from the observation that processes in organizations are the least understood and least managed level of performance (Rummler and Brache, 1995). Hammer and Champy (in Van-Der-Merwe, 2002) noted that business people are not 'process-oriented,' but rather focused on tasks, on jobs, on people, on structures, but not on processes.

Many firms do not have formal methods in place to evaluate and process information, and the quality of the new-product decisions generally only becomes evident long after the screening stage (de Brentani, 1986). Likewise, Cooper, Edgett, et al. (1997) pointed out that although leading organizations use maximization models, scoring models, bubble diagrams, and other portfolio selection tools in the early phases, it is difficult for managers to make sense of all the related information. Simon (1957) reported that these cognitive limits of people can be overcome by utilizing organizational-structural mechanisms. Relative to NPD, some of the organizational structural mechanisms include the process and success factors that are utilized by the organization to develop new products. In the next section, the more frequently referenced NPD process models are reviewed from the perspective of structural mechanisms for reducing the uncertainty of the innovation process.

D. Overview of NPD Models

To break down the NPD innovation process into manageable pieces of information, several models have been proposed for organizing the necessary work and the decision process. NPD models provide frameworks, which are considered part of the organizational-structure mechanisms, for product development. The research shows that use of a development model improves metrics such as development cycle time; however, the overall average product success has remained relatively flat (Adams, 2004). In some instances, the NPD models have phases or stages for what could be considered front-end activity but it has been noted that most of the NPD process models focus on the nature of the activities and decisions after a project has received the go-ahead to move into the development segment (Reid and de Brentani, 2004). Several of the models are summarized next with phases containing some type of front-end element underlined in the discussion.

Clark and Wheelwright (1993) depicted a process model across four phases: <u>concept development</u>, <u>product planning</u>, product and process engineering, and pilot production/ramp up. Cooper's (2001) general Stage-Gate® model included five formal stages and five corresponding gates for <u>scoping</u>, <u>building the business case</u>, development, testing and validation, and product launch. Cooper, Edgett, and Kleinschmidt (2002a; 2002b) subsequently added ways to optimize the Stage-Gate® model based on level of uncertainty or project size.

McGrath (1996) described a five-phase development model consisting of concept evaluation, planning and specification, development, test and evaluation, and product release with decision gates at the conclusion of each phase. Clausing (1994) described what he termed a *total quality view* of the development process with a four-phase model: concept, design, preparation, and production. Within this framework, he defined specific tools that can be used in each phase.

Quality initiatives, particularly in automotive-related products, introduced Advanced Product Quality Planning (APQP), which is now widely applied (Stamatis, 1998; Carbone, 2005). APQP is a five-phase model that defines in detail what must be accomplished in each phase of a project. The APQP model provides no recommendations for the front-end segment and assumes that a product idea exists and a decision to develop the product already has been made.

Although the development models have improved the NPD process decision making and cycle time, the models alone do not provide all of the details needed for new-product management. Tzokas, Hultink, et al. (2004) collected 234 responses to evaluate the importance of the various NPD stages and gates and noted that managers would find little in terms of success factors in the relevant model-based literature. Likewise, Griffin and Hauser (1996) pointed out that such models would not solve all a firm's product development problems. Neither do the models clarify which success factors are applicable for various levels of product innovation in specific industries. Overall, the NPD models are general and the front-end segment has not been well defined or integrated into these models. In the next section, the published models specifically for the front-end are summarized.

E. Front-End Development Models

Specific process models were proposed by several researchers to help structure the front-end of NPD in order to deal with the uncertainty and information of this segment. Table 2.1 summarizes the most widely published front-end models. Smith and Reinertsen (1998) specified a three-stage front-end model for front-end planning and decision making. In the first stage, a project proposal is presented; in the second stage, a business plan for financial and market justification is prepared; and in the third stage, detailed project planning and specifications occur. Paul (1996) studied business-to-business product development and proposed a general three-step approach of internal idea screen, concept development and testing, and business analysis.

Khurana and Rosenthal's (1998) front-end model consists of three phases. In the Pre-Phase-0, they suggest a preliminary opportunity identification and a market and technical assessment, parallel to the product and portfolio strategy evaluation. In Phase 0, the product concept is defined. Phase 1 is used for product feasibility and project planning. Another key point argued by these authors is that the front-end process should be adapted to the innovation level of the product, the target market, and the organizational context.

Cooper (1997) modified the Stage-Gate® model to include two "homework" or predevelopment stages. Stage 1 is the preliminary investigation and Stage 2 is called the detailed investigation or business-case preparation. Kim and Wilemon (2002b) did not contribute a study to the literature, but they proposed several ideas for the front-end based on their review of the literature. They summarized a three-step generic front-end model to encompass idea-generation capture, idea screening, and evaluate and document decisions. Koen, Ajamian, et al. (2001) described the New Concept Development (NCD) model for the front-end. These authors critiqued the shortcomings of previous sequential models and proposed a circular and iterative approach in of five activities which ideas can enter the front-end from different points (Belliveau, Griffin, et al., 2002).

Table 2.1 Summary of Front-end Process Models

Author(s)	Description
Smith and Reinertsen, 1998	Three-Stage Front-End Model Stage 1: Project proposal Stage 2: Business plan Stage 3: Detail project plans and product specifications
Paul, 1996	Three-Step Front-End Model Step 1: Idea screen Step 2: Concept development and testing Step 3: Business analysis
Khurana and Rosenthal, 1998	A Three-Phase Front-End Model Pre-phase 0: Preliminary opportunity identification and market and technical assessment in parallel with product and portfolio strategy evaluation Phase 0: Product concept is defined Phase 1: Product feasibility and project planning
Cooper, 1997	Two Stages in the Front-End of the Updated Stage-Gate® model Stage 1: Preliminary investigation Stage 2: Detailed investigation and business-case preparation
Kim and Wilemon, 2002b	Three-Step Front-End Model Step 1: Idea-generation capture Step 2: Idea screening Step 3: Evaluation and document decisions
Koen, Ajamian, et al., 2001	Circular Model not necessarily sequential Opportunity identification Opportunity analysis Idea generation and enrichment Idea selection Concept definition

In their review of three research and development (R&D) projects at two companies, Nobelius and Trygg (2002) found that the front-end activity varied. Nobelius and Trygg claimed that the front-end models from Smith and Reinertsen, as well as Cooper, "lack specific context" (p. 332). In addition, Nobelius and Trygg viewed Cooper as overemphasizing the danger of avoiding any vital activity and criticized Khurana and Rosenthal as proposing that the "front-end activities are to be seen as interrelated, and avoiding one of them contributes to project failure" (p. 338). Instead, Nobelius and Trygg argued that the front-end must be flexible and based on the type of project, staffing situation, and overall company situation. Based on their small sample size of three different projects, each with a different innovation level, it is difficult to draw conclusions. However, this is additional evidence of the lack of rigor and sample size of some prior front-end studies.

Although these models attempt to propose some structure for the front-end activities, no formal guiding process for integrating the information exists (Zahay, Griffin, et al., 2004). This sentiment was echoed by Salomo, Weise, et al. (2007) who noted a widespread use of the fuzzy front-end term without universal agreement on the activities that the front-end actually entails. Reid and de Brentani (2004) called for a search into a fuzzy front-end processes that would help firms achieve greater success in their efforts to develop new products. This is important given that the front-end has been called the most information-intensive phase of the NPD process where uncertainty seems to be the norm (Zhang and Doll, 2001; Zahay, Griffin, et al., 2004).

The shortcomings of these models are that they are high level, lack details on critical activities, and were not fully validated for specific industries at particular innovation levels based on previously reported success factors. An improved front-end process may facilitate better selected products to move into the development phases to take advantage of the already improved and efficient processes of that segment. To create an improved front-end process, an organization must understand the success factors of the front-end. The next section addresses how new-product success can be measured, which then leads to the investigation of prior reported success factors which may contribute to increased success.

F. NPD Success Measures

The literature on innovation and new products has documented that many new products released to the market are either not as successful as expected or, in some cases, outright failures. From the PDMA studies of 1990, 1995, and 2003, the market-success numbers are reported as 58, 59, and 58 percent, respectively (Adams, 2004). Ettlie and Elsenbach (2007) validated a similar launch success rate of 60 percent. These market-success numbers are for products that are *actually launched* in the marketplace. The numbers do not reflect products that were canceled or failed for technical problems, competition, company resources, priorities, change of market conditions, and so forth within any of the previous segments of the development funnel. Based on a review of invention disclosures, patent filings, and technical papers, research shows that as many as 3,000 raw ideas may be required to have one success (Stevens and Burley, 1997). The success rates for the combined development through launch phases have been noted as low as 25 percent (Griffin, 1997; Cooper, 2001).

It has been reported that, typically, seven to ten evaluated ideas are required to achieve one market success (Cooper, 2001; Adams, 2004). The failure rates from the front-end to the market launch have been plotted in what are called NPD *mortality curves* (Griffin, 1997). The product mortality numbers are shown for each segment in Figure 2.3. Based on these data, if ten ideas are "evaluated" in the front-end, on average, four will proceed to the development segment. Of the four ideas that enter the development segment, on average, 1.7 will be launched to market. Of the 1.7 products launched, only one will be a success. The measurement of success depends on the criteria for success and where in the process the measure is taken.

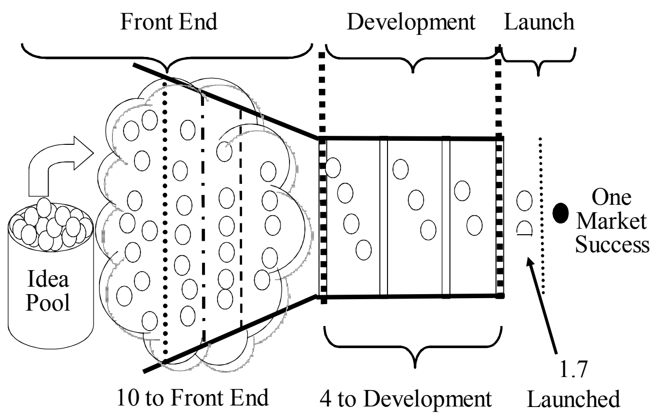

Figure 2.3. NPD Model with Typical Mortality Values per Adams (2004)

Success can be measured from the internal and the external perspective. The internal perspective is also known as the *operational perspective*. Operational performance measures include product quality, cost, and development time. The external perspective is also known as the market-based perspective. External performance measures capture marketplace outcomes such as product sales, customer satisfaction, profitability, and market share. Tatikonda and Montoya-Weiss (2001) concluded that there was a positive association between achieving operational measures and the resulting market outcome measures. This finding has been replicated by other researchers (Swink and Calantone, 2004).

The question then becomes is the project only a success when the product becomes a success? In actuality, the full story on success may be difficult to define in black and white terms. As described by Connell, Edgar, et al. (2001), there are projects that can be "troubling successes as well as good failures." They labeled the Apollo 13 program the latter due to all the learning and preparedness for the future that resulted from the mission that missed original objectives. The 3M Post-it® Notes product was labeled as a good failure due to the unintended consequences of an innovation that missed original specification but resulted in significant revenue for the company.

What then is the best way to distinguish between project and product success and how should each be measured? A project is defined as a temporary endeavor undertaken to create a unique product, service, or result (Project-Management-Institute, 2004). Project managers focus on the end date of their project, product managers want their products to live a long life and be highly profitable (Kerzner, 2006). The activities and resources of the product lifecycle are different during the new product development project as compared to after the launch. It is not reasonable then to use the same measures of success during the development of a product, across the project lifecycle, as would be used following the market launch, across the product lifecycle. Such complications may partially explain why the literature has significant variation in the measure type and the number of measures used by each study.

A known limitation of many prior studies was the utilization of a single success-measurement item (Zirger and Maidique, 1990; Moenaert, DeMeyer, et al., 1995; Droge, Calantone, et al., 2008). Singular items were most often dealing with some version of financial success. Other studies did not include any financial or technical measure and instead measured activities associated with the NPD process. In a study by Kahn, Castellion, et al. (2005) with responses from 156 apparel and textile manufacturers to gauge market orientation and interdepartmental integration, the two performance measures used were an evaluation of "pre-launch activity" and "launch and post-launch activities." Limited success-measurement items have been the subject of debate in the literature. For example, in the study by Calantone, Chan, et al. (2006), the authors admitted that the single measure of success they used "can be questioned on the grounds that prior studies have often used multiple indicators" (p. 419).

The more robust studies used multiple types of success measures. Sherman, Berkowitz, et al. (2005) used measures of market-forecast accuracy and whether the forecast for the customer requirements were met. In a multi-industry study, Ettlie (1997) measured perceived success from 126 respondents across the measures of technical requirements, budget, schedule, and commercial success. The commercial success was broken down further into perceived market share and ROI attainment. Akgün and Lynn, et al. (2006) used 10 external measures of sales including profit, market share, ROI, and volume. The authors removed the "met technical performance" measure after it failed to load with the other measures on the success construct.

Given the various types of success perspectives, it is not surprising that the literature shows that the success measure used is dependent on the innovation level of the product (Manion and Cherion, 2009). Table 2.2 presents the product innovation level definitions applied in this research (Griffin and Page, 1996; Adams, 2004). Innovation categories range from the most complex, new to the world (NTW), to the least complex, the cost reduction (CR) level.

Griffin and Page (1996) provided recommendations for which success measures were most useful based on the product-innovation levels of newness to the firm versus newness to the market (Figure 2.4). The measures, while similar across the levels, do have subtle differences, but are all market-based. To further explain the multidimensional aspect of project success, Shenhar, Dvir, et al. (2001) classified success across four dimensions: project efficiency, impact on the customer, business success, and preparation for the future. They stated that financial measures alone do not fit well with today's dynamic markets, multiproduct firms, and high fixed cost environments (Shenhar, Dvir, et al., 2001, p. 701). The authors also noted that the operational mindset is clearly reflected in the project management literature, with measures for time, budget, and performance as the main indicators for project success. Even when taken together, such measures can lead to incomplete and misleading assessment. Such operational measures alone may count a project as a success that met time and budget constraints, but in the end it failed to meet customer needs and requirements. Their classifications captured both market-based and operational success measures to provide a more complete perspective.

Table 2.2 Product Innovation Level Definitions

New to the World (NTW): New products that create an entirely new Market.
New to the Company (NTC): New products that, for the first time, allow a company to enter an established market.
Additions to Existing Product Lines (AEL): New products that supplement a company's established product lines.
Improvements in / Revisions to Existing Products (IM): New products that provide improved performance or greater perceived value and replace existing products.
Repositionings (RP): Existing products targeted to new markets or market segments.
Cost Reductions (CR): New products that provide similar performance at lower cost.

	High	**New To Company (NTC)** • Market Share • Revenue or Satisfaction • Met Profit Goal • Competitive Advantage		**New To World (NTW)** • Customer Acceptance • Customer Satisfaction • Met Profit Goal or Internal Rate of Return (IRR)/ROI • Competitive Advantage
Newness to the Firm		**Improvements (IM)** • Customer Satisfaction • Market Share • Revenue Growth • Met Profit Goal • Competitive Advantage	**Addition to Existing Lines (AEL)** • Market Share • Revenue/Revenue Growth • Satisfaction/Acceptance • Met Profit Goal • Competitive Advantage	
	Low	**Cost Reduction (CR)** • Customer Satisfaction • Acceptance or Revenue • Met Margin Goal • Performance or Quality	**Repositioning (RP)** • Customer Acceptance • Satisfaction or Share • Met Profit Goal • Competitive Advantage	
		Low	**Newness to the Market**	**High**

Figure 2.4. Product Innovation Success Measures (Griffin and Page, 1996).

Many researchers measured success based on a perceived measurement scale. According to Calantone, Chan, et al. (2006, p. 415), "A perceived measure of performance was used because it permits comparisons across firms, based on managerial assessments within their own industry." The perceived subjective success measure also has been used in the NEWPROD model and research of Cooper (1985). The validity of this approach is supported by work that has shown perceived measures to be correlated with objective performance (Couillard, 1995; Song and Parry, 1997; Salomo, Weise, et al., 2007; Yoo and Park, 2007).

The conclusion is that success should be viewed from multiple dimensions and that operational success is related to market success. A study on product success must also consider the innovation level of the product. Success, of course, is the dependent measure that relies on an understanding of the factors that contribute to a new product's success. The next section covers the reported NPD success factors, which is followed by a review of those factors specifically for the front-end.

G. New Product Development Critical Success Factor Studies

With the understanding of which success measures to apply based on innovation level, new-product projects must be organized around the factors that could lead to improved product success. In a broad study of variables, Cooper and Kleinschmidt (1996) reported nine success factors in what they termed the NEWPROD model. The factors were (1) high-quality new-product process, (2) a defined new-product strategy, (3) adequate resources of people and money, (4) the right R&D spending, (5) high-quality new-product team, (6) senior-management commitment, (7) innovative climate and culture, (8) cross-functional team, and (9) senior-management accountability. The NEWPROD model was criticized as not being categorically simple enough for companies to use to help them measure or manage strategically dissimilar projects (Griffin and Page, 1996). Calantone, DiBenedetto, et al. (1999) critiqued the NEWPROD model, pointing out several limitations of the historical nature of the database and a singular focus on market success.

In a study of four successes and four failures, Connell, Edgar, et al. (2001) described what they defined as five critical innovation success factors for product development: executive direction, a project team, an innovation strategy, internal factors, and external factors. The internal and external factors in their summary covered a long list including: infrastructure, team structure, knowledge use, policies, procedures, economic, regulatory, social, political, supply chain, competition, creditors, and more. Lynn and Akgun (2003) used surveys and interviews in various industries to evaluate 117 new-product projects and listed four positive critical success factors: teamwork, cross-team communication, vision clarity, and market-niche assessment, as well as one negative relationship associated with formal within team communication. The success was measured using financial measures and expectations of the customer and senior management.

In a study of the integration of marketing and operations perspectives, Tatikonda and Montoya-Weiss (2001) focused on the stages of execution following the "go ahead." The 120 respondents came from various industries based on the PDMA membership database and Manufacturing Executives Forum. The study focused on process factors and product novelty as well as the corresponding impact on internal operational success and market outcomes. The results showed that the organizational factors of process concurrency, formality, and adaptability were positively associated with achievement of operational outcome targets for product quality, unit cost, and time to market. Furthermore, operational outcomes were shown to predict market outcomes of customer satisfaction and relative sales.

A study based on responses of 202 manufacturers in 41 different industries from the Fortune 500 list focused on four success factors: proactive strategic orientation, organizational structure, innovativeness, and market intelligence (Droge, Calantone, et al., 2008). A singular financial measure for success was shown to vary depending on environmental turbulence.

In a study across a range of electronic industries (i.e., hardware, software, equipment, and telecommunication), Zirger and Maidique (1990) evaluated one successful and one failed project across a sample of 172 new products. This study was exploratory and classified the results into eight factors: (1) R&D excellence, (2) marketing and manufacturing competence, (3) product value, (4) technical performance, (5) management support, (6) product synergy, (7) weak competitive environment, and (8) large and growing market. The survey used a single success rating based on financials from major loss to major profitability on a 10-point scale.

Montoya-Weiss and Calantone (1994) used a meta-analysis of 47 studies in the NPD literature to summarize reported success factors. The authors reported 18 factors leading to product-development success in four categories: strategy, market environment, development process, and organizational aspects. However, they discovered that the literature was inconsistent in terms of which factors were included in each study and which statistics were reported. They charged that the research remains exploratory in nature with many studies seeking to identify determinants of success/failure as though from scratch. Brown and Eisenhardt observed that much of the literature was broad-brushed, reading like a 'fishing expedition' with too many variables, where it was not uncommon for a study to report 10 to 20 or even 40 or 50 important findings (1995, p. 353). In a similar theme, Balachandra and Friar (1997) reviewed the literature and reported a lack of consistency in the factors among the studies: 48 studies showed positive effect and 39 studies showed negative effect from various factors. These reports are consistent with the findings of the literature review for this dissertation. Many studies were exploratory to identify factors, lacked multidimensional success-measurement, and rarely controlled for innovation level. In addition, it was observed that these studies attempted to cover a significant portion of the entire NPD cycle or had a specific focus on a certain factor area. Industry demographics also varied widely across many of the studies.

Given the volume of prior research regarding success factors, Poolton and Barclay (1998) summarized that the factors associated with success have largely failed to be translated into practical guides for action. They stated, "Firms *differ* with respect to the types of new products they produce, and that by virtue of their diversity, the success factors will vary both in their *number* and in their *relative intensity*. A more realistic scenario is that success factors can be tailored to the unique needs of the firm [emphasis original]" (p. 210). Furthermore, specifying the innovation level is an important consideration in any study (Lee and O'Connor, 2003; Salomo, Weise, et al., 2007).

It is apparent that knowledge for the NPD success factors has been generated, but the understanding is far from complete when it comes to taking action to improve product success. The next section summarizes the literature specific to the success factors of the front-end.

H. Critical Success Factors of the Front-end

The success factor literature review of the prior section provided evidence that some researchers have included certain aspects of the front-end in their overall NPD research. A study specific to the front-end critical-success-factors was completed by Khurana and Rosenthal (1997; 1998). The case-study method at 12 companies was completed through interviews with 90 new-product managers to test previously reported factors related to what was considered front-end activity. The authors formulated what they termed "a holistic process" for the front-end which they claimed was established by linking the business strategy, product strategy, and key decisions in the front-end. The researchers grouped the front-end success factors into four categories: new product strategy, product definition, project definition, and organizational roles. The study reported that increased success was perceived by the respondents when companies utilized the holistic approach in the front-end, but found only one company in their sample that had integrated all four dimensions. They reported problems in NPD suffered from a lack of disciplined execution on the activities of the front-end.

While the Khurana and Rosenthal research was a seminal work on the front-end, there are several limitations that require further study. First, although the interview method provides for rich exploration, it is subject to interviewer coding. The authors acknowledged that the interviews were semi-structured. Second, for their sample, the product-innovation level was not specifically controlled or specified. Third, there was no investigation of individual product success; instead, the focus was on the process of the front-end and the perception of market success at the firm level. Additional literature supporting the Khurana and Rosenthal factors of a holistic front-end is discussed next.

H.1 New Product Strategy (NPS)

The first success factor for the holistic front-end of new product strategy (NPS) covered the alignment of the product with the firm's overall strategy, project priority, portfolio planning, and balancing of risks (Khurana and Rosenthal, 1998). Having a clear definition of strategy and product alignment is critical for new-product portfolio positioning and priority. McGrath (2001) noted that product strategy must align with what he termed the organization's *core strategic vision*. To align product innovation and impact on performance, Bart and Pujari (2007) studied 86 responses about a firm's product-innovation charter, which they stated is “synonymous or even interchangeable” with the concept of a new-product strategy (p. 5). The authors reported that firms with a higher performance of innovation success specified more about their new product strategy. The measurement was based on a single item on the perceived overall organizational NPD success.

In order to effectively plan the portfolio and prioritize projects with respect to strategy the organization requires idea screening methods. Not only must a company do things right when developing a product, it also must choose the right products in the first place (Cooper, Edgett, et al., 1997). The screening process for strategic alignment of the product to evaluate risks, portfolio alignment, and project ranking has been studied by various authors. Portfolio management practices were captured through in-depth interviews at five companies covering the chemical, banking, consumer goods, and materials industries to summarize best practices (Cooper, Edgett, et al., 1997, a; Cooper, Edgett, et al., 1997, b). Lessons for evaluating ideas, alignment of the projects, and ranking were compared across the sample. The major conclusions were that the processes were unique to each company and the information was organized and used at different levels of detail.

Project prioritization was included as a measure in a study of 29 successes and 29 failures from 28 Utah based companies (Ottum and Moore, 1997). The study was focused on the impact of market information processing on the success dimensions of financial, customer satisfaction, and time and budget. Explicit definition of project priority was significantly related to market information that was gathered and shared. The use of such information was shown to positively impact success.

Ozer and Cebeci (2010) included a front-end concept screening item to evaluate firm-level financial success and rate of new-product introductions for domestic versus global markets.

The study encompassed a broad 122-person sample from any industry that responded that was listed on the China and Hong Kong Stock Exchange. The authors claimed that engaging in front-end activity had a positive impact on success. The method was based on four "yes" or "no" questions to test for: (1) concept screening, (2) concept testing, (3) market identification, testing, and strategy, and (4) business/financial analysis. It can be argued that the single item for "market identification, testing, and strategy" measured three different concepts. No reliability or validity test results were reported for the survey instrument. The other limitation of the survey design was the use of binary-response items.

Cooper (1997) reported that 88 percent of projects were deficient in front-end screening. In a dissertation by Liginlal (1999) a front-end decision support software model was built and simulated but not validated. Screening methods were evaluated at the firm level of 59 companies with no attempt to correlate to product success (de Brentani, 1986). Depending on the type of firm, there were differences in the number and type of screening criteria, but common criteria outweighed the firm-specific criteria. It is also recognized that too formal a screening process will lead to less risk taking and the possibility of missing a "big winner" (Schmidt and Calantone, 1998; Reinertsen, 1999).

H.2 Product Definition

The second front-end success factor identified was the definition of the new product (Khurana and Rosenthal, 1998). This factor includes early product definition, the setting of specifications or targets, a customer needs analysis, a market and technology assessment, and prioritization of product features. For successful product development, Khurana and Rosenthal (1997; 1998) recognized that the ever-changing technology in the marketplace may cause engineers to add unneeded complexity. They highlighted that during the front-end decision making, features must be added only as required by the assessment of the market, technology capability, and customer requirements through early and sharp product definition. Some have suggested that the product specifications be set prior to detailed planning (Buggie, 2002), whereas in the areas of lean product development and set-based concurrent engineering, it was proposed that targets, rather than specifications, should be set during the early phases (Sobek, 1997; Morgan, 2002). Ward (2007) suggested that the "lock-in" of a design should occur later, rather than earlier, to allow teams to learn and experiment with multiple solutions and tradeoffs.

Flint (2002) discussed the integration aspects of customer needs to improve the product-definition aspect during the front-end. Langerak, Hultink, et al. (2008) noted that sales volume was strengthened through a strong product advantage which required an understanding of the market and technology. Methods for a customer-needs analysis and feature priority are explained in the literature as leading to improved success (Cristiano, Liker, et al., 2000). More specifically for product functionality prioritization, the literature points to various tools and methods organizations may use, such as Pugh concept selection and Quality Function Deployment (QFD) (Clausing, 1994; Griffin and Hauser, 1996).

In the specific case of high technology industry, eleven exceptional innovators, who were inducted into the Engineering Hall of Fame in 2002, were interviewed by Griffin, Price, et al. (2009). The eleven innovations mentioned included at least six direct semiconductor-technology related products developed between 1958 and the early 1980's. From the process perspective these exceptional innovators emphasized the front-end activities of product planning, assessment, and deep customer knowledge, prior to the usual start of the development process.

A number of marketing and technical assessments have been included in NPD success factor studies. Based on interviews of 123 commercial successes and 80 commercial failures, the preliminary marketing assessment was rated as one of the weakest activities of the NPD process activities (Cooper and Kleinschmidt, 1986). Calantone, DiBenedetto, et al. (1993) included preliminary marketing and technical assessment items as part of their research on new-product success. The main focus of their study was the role that firm level organizational structure had in supporting marketing and technical activities for NPD. The survey responses were from 142 manufacturing-industry senior managers. For their sample, they showed that marketing skills had a greater influence on success than marketing activities, but they added the caveat that the skills likely contributed to better activity execution. Calantone, Schmidt, et al. (1997) included within their survey instrument 3 items on screening, preliminary market assessment, and preliminary technical assessment. The study asked respondents to score subjectively the items relative to their direct competitors and also used a single success measure based solely on profitability. The authors found that in a very competitive and hostile environment, firms may skip certain activities to speed development. They claimed that skipping activities can reduce significantly the odds of success.

H.3 Project Definition

Project definition was the third success factor identified for a holistic front-end (Khurana and Rosenthal, 1998). This factor encompasses resource-allocation planning, contingency planning for both technical and market considerations, and skills assessment for engineering and production. Moenaert, DeMeyer, et al. (1995) included skill and resource-allocation acknowledgment in their research on the communication between R&D and marketing to understand uncertainty reduction during the front-end. The study which included chemical, industrial-machinery, plastics, glass, metal-products, information-technology hardware suppliers, textiles, and “a wide diversity of other industries” measured success with two items related to meeting commercial success. The authors analyzed survey responses from 40 successes and 38 failures. They reported that more innovative products require higher skills and increased allocation from the innovation team during the planning phases. Their results on resources and skills overlap with the fourth factor of organizational roles and communication that will be described below. In the study by Calantone, DiBenedetto, et al. (1993) (discussed above under the product definition section) the authors included items to evaluate the skill level for marketing, R&D, engineering, and production. Salomo, Weise, et al. (2007) evaluated contingency planning across 132 projects in 64 companies in various industries, and the front-end variable they included for project risk planning was significant for innovation success.

Competency of engineering and manufacturing for NPD was included in the success factor study described earlier by Zirger and Maidique (1990). Success was measured by a singular financial measure. The resource competency factor was significant in their model, but was not as strong as other factors such as technical performance, value to the customer, synergy to the firm’s portfolio, and management support.

Contingency planning for technical and market considerations were included by Khurana and Rosenthal (1997; 1998) as a way to mitigate time to market delays. The importance of planning for risks on high technology semiconductor new product projects during early planning was considered as a key to improved success (Thompson, 2000). By planning for multiple product concepts, alternative technologies, and market changes, the innovation team can link product definition activity with appropriate risk mitigation during project definition.

To evaluate the impact on manufacturing readiness, Liker, Collins, et al. (1999) reviewed design and manufacturing integration from the perspective of the Burns and Stalker (1961) mechanistic-versus-organic organizations. They concluded that the organizational structure for NPD is more complex than the simple organic-mechanistic dichotomy may suggest. Their research of 74 manufacturing managers in various industries suggested that a form of mechanistic-type practices is a greater benefit at the point of manufacturing integration than at the front-end. This view contributes to the organizational structure agility needed at the front-end that was already highlighted in Calantone, DiBenedetto, et al. (1993). Organizational roles and structure are covered more explicitly in the fourth identified factor.

H.4 Organizational Roles

The fourth factor for a holistic front-end was organizational roles (Khurana and Rosenthal, 1998). This construct includes identification of the team, project manager role, executive sponsorship, and organizational communications. The study of organizational structure and impact on collaboration aspects in organizations has long been investigated in the management-science literature (Burns and Stalker, 1961; Lawrence and Lorsch, 1967). Team organization in the front-end is typically small but is often recommended to be cross-functional (Ottum and Moore, 1997; Kim and Wilemon, 2002, b). In a study of 540 product managers in multiple industries and innovation levels, Larson and Gobeli (1988) concluded that NPD team structure impacted perceived success. Although their study did not measure commercial success and was not focused solely on front-end factors, the recommended team structure was a form of balanced, matrix, or project teams with a project manager identified to lead the team. However, in one example from a case-study evaluation of Nortel's front-end process, the authors described how the company considered cross-functional teams in the front-end to be inefficient when evaluating product ideas (Montoya-Weiss and O'Driscoll, 2000). The authors instead recommended that the evaluation be left to a few expert individuals.

Executive or champion-like sponsorship has been studied for the impact on new-product success. Top-management support has been shown to positively impact new-product success (Cooper and Kleinschmidt, 1987). Tighe (1998) described the essentials on how NPD professionals must sell their projects to potential sponsors to gain support. The role of senior management for high NPD collaboration teams was also studied using the interview method (Jassawalla and Sashittal, 2001). For more collaborative NPD teams, senior managers were involved in the project to select team leaders, decentralize decision making to the team, provide the team with necessary information and resources, and encourage the team to take risks and experiment with creative ideas. This study also identified the characteristics of team leaders for collaborative NPD projects. The authors summarized that successful team leaders orchestrated higher levels of communication and information sharing, fostered a team environment in which members understood the goals and strategy, developed the team members' interpersonal and process skills, and networked outside the team to bring in needed information and resources missing by the team.

Organizational communication processes for NDP teams include how the communication is organized through cross-functional mechanisms (Olson, Walker, et al., 2001). From interviews and surveys of the project leaders and team members involved on 34 projects in 9 different industries, the researchers concluded that cooperation among these groups depended on both the development-process phase and the innovation level of the product. In NPD teams that failed, communication was sparse and was reported to even be discouraged (Lynn and Reilly, 2003). In a study that did not adjust for innovation level and did not measure external success, collaboration on 50 projects through concurrency of R&D with manufacturing activities at 14 international companies demonstrated that the collaboration was a necessary but insufficient condition for meeting the operational success measures of project time, cost, quality, function, and team satisfaction (Hauptman and Hirji, 1996).

It was reported by Zahay, Griffin, et al. (2004) that a process to integrate front-end information and its collaboration does not yet exist in many organizations. They concluded that it had been difficult for researchers and practitioners to understand how to manage the front-end effectively due to the complexity of types and forms of information that need to be managed. Researchers including Reid and de Brentani (2004, p. 172) noted that "a search for better processes in support of the fuzzy front-end appears to be called for in order to help firms achieve greater success in their efforts to develop new products." The front-end is also the point of most leverage as an idea is taking shape and being evaluated. By better understanding the process and critical success factors, managers and teams will be better prepared to deal with the information for decision making and learning.

In conducting the literature review, no particular prior study evaluated the holistic front-end process of NPD based on the constructs of previously reported front-end success factors. The next section presents the conceptual model to evaluate the reported front-end success factors on success at the project level for new products at a controlled level of innovation.

I. Conceptual Model for the Research

In the research for this dissertation, the holistic front-end model proposed by Khurana and Rosenthal (1997, 1998), which was based on reported front-end success factors, is expanded and validated using more robust methods. The conceptual model developed for this research is shown in Figure 2.5 in the form of a nomological network. A nomological network shows the network of relationship for research (Cronbach and Meehl, 1955). The model is based on the literature review of the NPD front-end critical success factors and new-product success.

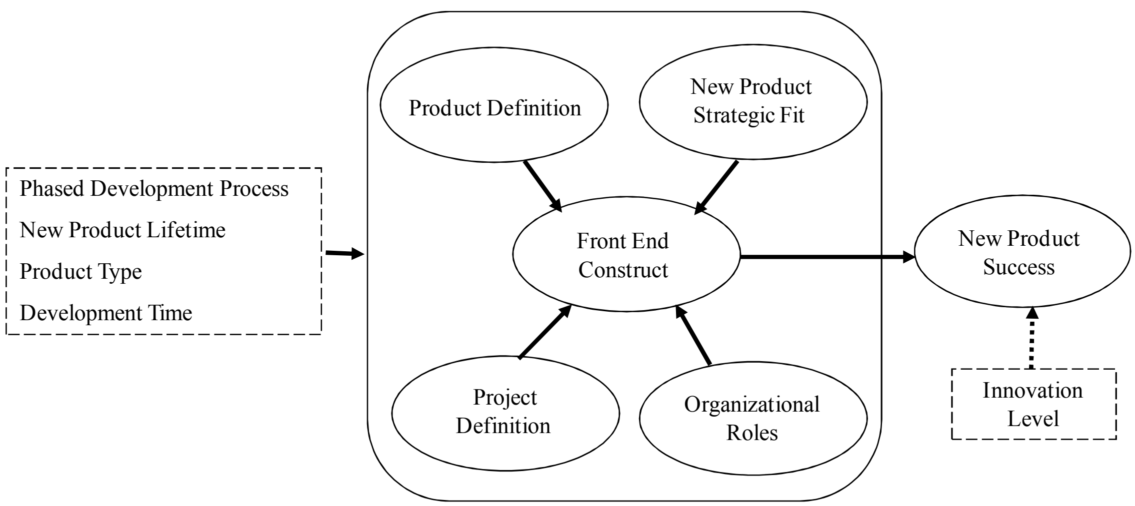

Figure 2.5. Conceptual Model Relating Front-End Factors to New-Product Success

The antecedents to the model are thought to have an impact on how an organization may structure the front-end process. The variables for this research are a phased-development process, new product lifetime, type of product, and development time. From the literature review, a phased-development approach was shown to be an enabler of a NPD process. The research was to include only those organizations that had such a phased-based process in place for NPD. Development time and new product lifetime, as shown on the earlier NPD funnel and product-lifecycle curve (Fig. 2.1), will vary by industry, innovation level, and product type. The front-end factors and process applied may then be selected depending on the expected product development lifecycle as well as the total life of the product. The type of product, which is based on the type of industry, would also impact how the front-end was structured. For these reasons, these are variables that need to be understood and possibly controlled for in the data collection process.

The front-end construct of the model consists of four success factors based on the holistic front-end model as described by Khurana and Rosenthal (1998). The constructs for this research are the factors of new-product strategic fit, product definition, project definition, and organizational roles. The literature review covered additional research in support of each of these critical front-end factors; however, no research was discovered that validated this particular set of factors for the holistic front-end and the corresponding impact on product success.

The consequence variable in the model is the new product success. As pointed out earlier, success should be considered from both the operational and the market success perspectives (Shenhar, Dvir, et al., 2001). The operational or internal success is defined as the internal measures which include the meeting of product scope, project budget, and development time. Market or external success for this construct includes external outcomes such as product sales, customer satisfaction, profitability, technical performance, and preparation for the future.

The model accounts for innovation level as recommended by prior research (Lee and O'Connor, 2003; Salomo, Weise, et al., 2007). Innovation level is shown as a moderator variable that may impact the success of the product. The definitions for each construct of the model are listed in Table 2.3 along with the key references that were covered earlier in this chapter.

J. Summary

The literature review of this chapter, focused on the process and success factors of NPD. The new-product life cycle, definitions of uncertainty and innovation, process models, success measurement, and success factors were described. A major shortfall of existing product-development research for success factors stems from general studies that often do not build on previously reported success factors. Additionally, single measure or limited items of success dimensions continue to dominate the literature. The prior literature has not covered the validation of success factors of the front-end and the impact on product success. The conceptual model was presented to relate the variables of the critical success factors to product success. The prior research pointed to the need to capture and possibly control the innovation level of the products and the type of industries in the study.

Table 2.3 Construct Definitions and Sample of Sources

Construct	Defined Construct Domain	Key Sources
New Product Strategic Fit (NPS)	Strategic alignment between the new product and the organizational strategy, project priority, product portfolio planning, and balancing for risks.	(de Brentani, 1986; Cooper, Edgett, et al., 1997a; Cooper, Edgett, et al., 1997b; Ottum and Moore, 1997; Khurana and Rosenthal, 1998; Schmidt and Calantone, 1998; Liginlal, 1999; Reinertsen, 1999; McGrath, 2001; Bart and Pujari, 2007)
Product Definition (PD)	Early definition, specifications/targets, market and technology assessment, customer needs analysis, and product-feature priority.	(Cooper and Kleinschmidt, 1986; Calantone, DiBenedetto, et al., 1993; Clausing, 1994; Moenaert, DeMeyer, et al., 1995; Griffin and Hauser, 1996; Calantone, Schmidt, et al., 1997; Sobek, 1997; Khurana and Rosenthal, 1998; Cristiano, Liker, et al., 2000; Buggie, 2002; Flint, 2002; Morgan, 2002; Ward, 2007; Langerak, Hultink, et al., 2008; Ozer and Cebeci, 2010)
Project Definition (PJ)	Resource planning, planning for technical and market contingencies, and skill level planning.	(Zirger and Maidique, 1990; Calantone, DiBenedetto, et al., 1993; Moenaert, DeMeyer, et al., 1995; Khurana and Rosenthal, 1998; Liker, Collins, et al., 1999; Salomo, Weise, et al., 2007)
Organizational Roles (OR)	Project team identified, project manager role, organizational communication processes, and executive sponsorship.	(Cooper and Kleinschmidt, 1987; Larson and Gobeli, 1988; Hauptman and Hirji, 1996; Ottum and Moore, 1997; Khurana and Rosenthal, 1998; Tighe, 1998; Jassawalla and Sashittal, 2001; Olson, Walker, et al., 2001; Kim and Wilemon, 2002b; Lynn and Reilly, 2003)
Success Measures	Operational performance measures include product scope, budget, and development time; external performance measures include marketplace outcomes such as product sales, customer satisfaction, profitability, technical performance, and preparation for the future.	(Griffin and Page, 1996; Shenhar, Dvir, et al., 2001; Tatikonda and Montoya-Weiss, 2001; Spanjol, 2003; Sherman, Berkowitz, et al., 2005)
Innovation Level	Based on PDMA definitions. See table 2.4.	(Griffin and Page, 1996; Cooper, Edgett, et al., 1997; Adams, 2004)

CHAPTER III

RESEARCH STATEMENT

A. Introduction

This chapter presents the research statement and hypotheses of the study in examining the relationship between the front-end critical success factors and new-product success. Although there has been significant research about NPD, there is still much to be learned to improve the success of released products. In particular, little empirical research has been conducted to determine whether the previously reported NPD front-end critical success factors are strong predictors of product success on a multidimensional scale. Furthermore, none of the previously reported studies were conducted to evaluate the front-end factors in a specific industry at a determined level of innovation.

B. Research Statement

The specific research statement for this dissertation is *The critical success factors of the front-end of new-product development are related to the perceived success of high technology industry new products*. A further focus of the research is on product innovations in the categories of new-to-the-company (NTC), product improvements (IM), and additions-to-the-existing-product-line (AEL) products.

The research does not consider all possible constructs that may lead to NPD project success for a firm. For example, this research topic does not include aspects of NPD that follow the launch from a marketing and sales perspective (Hultink, Hart, et al., 2000; Colarelli-O'Connor and Veryzer, 2001). New to the world (NTW) products, also termed *radical* or *discontinuous product innovations* (Lynn and Akgun, 2001) are not included in this research, as they reportedly have critical success factors specific to that innovation level (Colarelli-O'Connor and Veryzer, 2001; Rice, Leifer, et al., 2002; Griffin, Price, et al., 2009).

C. Hypotheses

The hypotheses are presented with the corresponding model representation for the relationships. The models for testing of the hypotheses are further elaborated based on the conceptual model of Figure 2.5.

Individual Front-end Success Factor Impact on New Product Success

New-product success is tested relative to each of the individual front-end critical success factors with direct relationships. Each factor is theorized to have a positive impact on the success from both the external and internal success perspective. Figure 3.1 represents the paths for the hypotheses.

H1a: New Product Strategic Fit is positively related to the new product project success from an external perspective.

H1b: New Product Strategic Fit is positively related to the new product project success from an internal perspective

H2a: Product Definition is positively related to the new product project success from an external perspective.

H2b: Product Definition is positively related to the new product project success from an internal perspective.

H3a: Project Definition is positively related to the new product project success from an external perspective.

H3b: Project Definition is positively related to the new product project success from an internal perspective.

H4a: Organizational roles are positively related to the new product project success from an external perspective.

H4b: Organizational roles are positively related to the new product project success from an internal perspective.

Effect of the Front-end Construct on New Product Success

The combination of the individual front-end critical success factors making up the holistic front-end construct is expected to have a positive impact on new-product success. The method of testing this specific model (Figure 3.2) with an unobserved variable noted as the "front-end."

H5a: Front-end critical success factor orientation is positively related to the new product project success from an external perspective.

H5b: Front-end critical success factor orientation is positively related to the new product project success from an internal perspective.

Moderating Effect

The innovation level of the product is expected to moderate the internal and external success of the product. Figure 3.1 shows the moderating effect on the two success dimensions.

H6a: The innovation level of the product will moderate the front-end variable impact on the internal success of the product.

H6b: The innovation level of the product will moderate the front-end variable impact on the external success of the product.

Internal Success Effect on External Success

The literature noted there is a positive relationship between internal success and external success (Figure 3.1). This effect will be tested to identify which of the individual measures of internal success are significant in relation to external success.

H7: Internal operational-based success is positively related to external market-based success of the product.

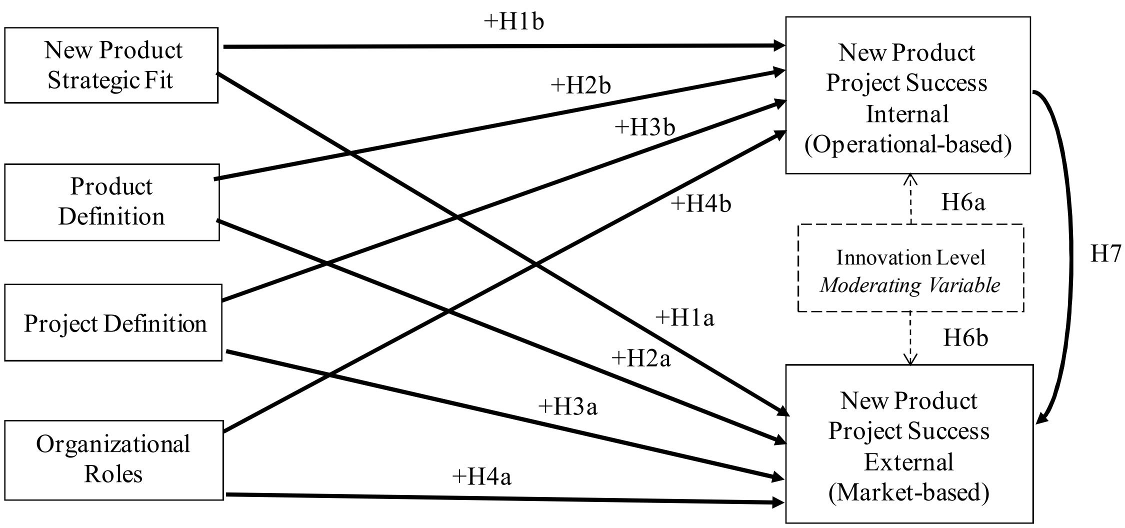

Figure 3.1. Model for Construct Effects on Success (H1 to H4; H6 and H7)

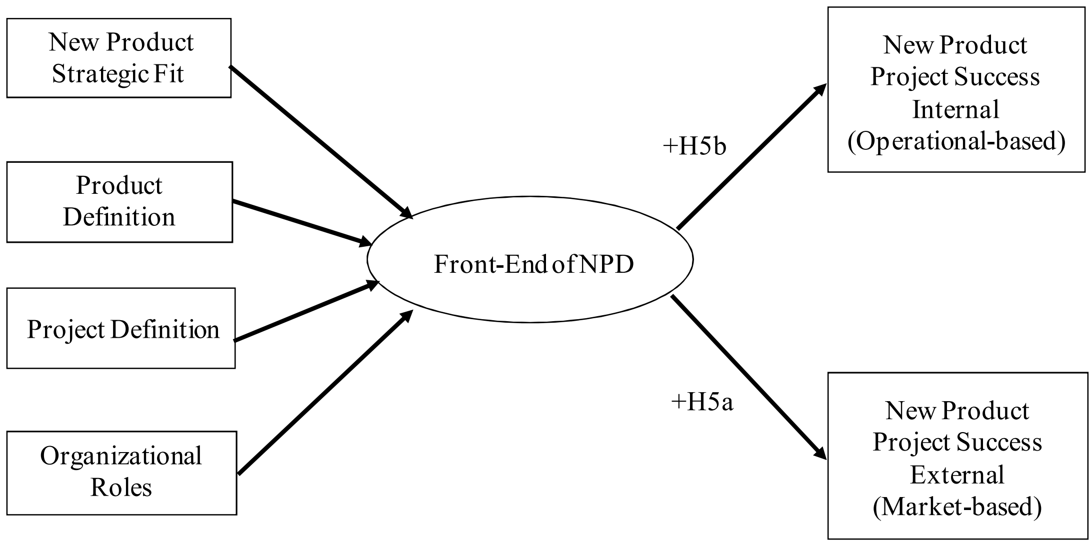

Figure 3.2. Model for Front-end Effects on Success (H5)

D. Expected Results, Benefits and Contribution

This research is an in-depth analysis of the front-end critical success factors at the project level, in the categories of new to the company (NTC), product improvements (IM), and additions to existing lines (AEL) product innovation levels, within one high technology industry. Multidimensional success from both the internal and external perspectives is evaluated. Montoya-Weiss and Calantone (1994) pointed to the lack of rigorous statistical analysis reported for NPD studies in the literature. Therefore, the data collected for this research are analyzed using correlation statistical techniques and multivariate procedures. Validity testing is completed for the survey instrument.

By testing the research hypotheses, it is expected that an improved framework will be developed for managing the critical segment of the NPD front-end that can contribute to increased product success. For organizations, this research contributes to understanding how the application of the front-end success factors impact the success of the product. For the academic community, this knowledge will lead to further investigation and research across industries and product-innovation levels. For the applied researcher, the findings will have a positive impact on the development pipeline by providing guidance for improved processes in the front-end of product development.

E. Summary

This research builds on prior success factors for NPD, focusing on the front-end. In particular, it focuses on product innovations in the categories of new to the company, product improvements, and additions to existing line type products. The purpose of the research is to improve the understanding of the success factors required for the front-end process in a high technology device industry. The additions to the knowledge base for this segment of the NPD process can then be extended to other industries for more general validation.

CHAPTER IV

RESEARCH METHODOLOGY

A. Introduction

In this chapter, the methodology is described for conducting the research. First, the chapter reviews the process for the creation and testing of the survey instrument through the use of the subject matter experts and pretesting. Second, the sample for the main study is described. Third, the analysis process is described that will be used to test the hypotheses which were presented in Chapter 3.

B. Research Method

While Khurana and Rosenthal (1997; 1998) utilized the interview method to specify the domain for what they termed the holistic front-end, there are aspects in additional literature for the overall NPD process, as well as specific to the front-end, which supported their findings (see chapters 2 and 3). However, no comprehensive study was discovered that validated the holistic front-end success factors. The Khurana and Rosenthal research also did not include the impact of the front-end success factors on the success of new products. This research serves to test the critical success factors of the front-end, for a particular industry and at defined levels of product innovation at the project level, with the corresponding impact on product success.

Data for this research could have been collected through observation, interviews, or surveys. Observational methods are typically time-consuming and applied to exploratory studies of limited sample size. One such example is found in the dissertation on new product development collaboration by Black (2002) where observational data were analyzed on two project cases. The interview method, while typically consisting of a larger sample than the observational method, has issues of coding, is time consuming, and is often best for exploratory research. As illustrated in the Khurana and Rosenthal (1997; 1998) research, 90 managers were interviewed at 12 companies to propose a model for the holistic front-end.

While observational methods and interviews are applicable when developing a theory, the survey method is more appropriate for validation studies. Since the focus of this dissertation was to validate prior reported front-end critical success factors, a survey methodology was chosen for collecting the data for this research. The key advantage of a survey based study is the ability to sample a significant number of respondents to statistically test the hypothesized model. The survey method allowed for the most cost effective distribution to the intended sample population that is geographically located around the world. The survey method provides for highly consistent responses due to the constrained choices which lead to a more robust method for post processing and analysis as compared to the interview or observational methods. The literature review phase for this research found no prior survey on the reported front-end success factors. Therefore a survey was developed to conduct this research.

C. Statistical Evaluation Methods

The survey was subjected to validity and reliability testing. Scale validity was achieved with a confirmatory factor analysis (CFA) (Hair, Tatham, et al., 1998). Sufficient correlation (greater than 0.30) as well as individual measures of sampling adequacy (greater than 0.50) were validated for each of the variables (Hair, Tatham, et al., 1998, p. 99). To test whether the variables were correlated with one another the overall Kaiser-Meyer-Olkin (KMO) measure for sampling adequacy with a requirement for a value greater than 0.50 was used. To further assess the suitability for factor analysis of the sample, Bartlett's test of sphericity was computed to validate that the correlation matrix was significantly different than the identity matrix. Component loadings of 0.4 or greater were set as the minimum required level to maintain an item. As noted by Hair and Tatham (1998, p. 111) factor loadings greater than +/ 0.30 are a minimal level; loadings greater than +/- 0.40 are considered important; and loadings greater than +/- 0.50 are considered practically significant. Cross loading above 0.4 were evaluated for any with differences less than 0.2 across components (Podsakoff, Ahearne, et al., 1997).

Cronbach's alpha was used to assess scale reliability for each construct. This measure of internal consistency is based on the correlations between each pair of items in the scale amongst respondents. An alpha benchmark greater than 0.5, which indicates adequate internal consistency, as recommended by Nunnally and Bernstein (1994), was applied. For the validity and reliability analysis, missing values were not imputed, thus there is a slightly lower than full sample size.

The data collected from the survey was used to test the hypotheses based on the model presented in Chapter 3. ANOVA, multiple regression, and structural equation modeling were used to test the hypotheses. ANOVA was used to compare variables in the data set such as product innovation level or demographic group comparisons. Multiple regression was used to test the relationships presented earlier in Figure 3.1.

Structural equation modeling (SEM) was used to examine the relationships of the endogenous latent variable labeled as the "front-end" on new product success (Figure 3.2).

SEM is a statistical method to test hypotheses where there are both observed and unobserved variables. The unobserved variables are known as latent variables. For the purpose of this research, the variable labeled the "front-end" in the model of Figure 3.2 is an endogenous latent variable because it is both an effect of prior variables and a cause on subsequent variables. A benefit of the structural model is that the latent variable is free of random error and the uniqueness that is associated with the actual indicators. The software package called Analysis of Moment Structures (AMOS) version 19 was used for the modeling.

Utilizing SEM analysis for this research adds additional insight into the proposed theory and hypotheses that factor analysis and regression alone cannot provide. However, SEM is not without complications. One issue is measuring the goodness-of-fit for the model. The specification of the model based on theory is critical. For additional confidence, fit is assessed through multiple indices. The selection of an appropriate fit measure to use is dependent amongst other things on sample size, estimation procedure, model complexity, and the validity of assumptions for the underlying data. The details on each fit measure are not repeated here as an exhaustive review of fit indices is provided in Byrne (2001) and Blunch (2008).
Table 4.1 is a summary of the fit indices used for this research. Typical of statistical methods, there are guidelines for ranges of acceptable model fit. As noted by Blunch (2008, p.113) the fit indices are grouped into classification. In selecting fit measures to report, Blunch stated the choice, "boils down to choosing the best fit index from each group," (p. 117). An explanation of the fit indices used for the model of this research will be covered in the corresponding analysis section.

Table 4.1 SEM Goodness of Fit Measures

Fit Index	Description	Desirable Range
Root mean square residual (RMSE).	RMSE represents the square root of the average or mean of the covariance residuals. Based on the non-central chi-square distribution. Proposed as analogous to the standard error of the estimate in traditional regression (Blunch, 2008).	Zero represents a perfect fit, but the maximum is unlimited. Less than .08 (Browne and Cudeck, 1993) with 0.1 indicating mediocre fit (Byrne, 2001).
Comparative fit index (CFI). Also known as the Bentler Comparative Fit Index.	CFI compares the model of interest with some alternative, such as the null or the independence model. It is a relative fit measure.	Values that approach 1 indicate acceptable fit. CFI is not too sensitive to sample size (Fan, Thompson, et al., 1999).
Normed fit index (NFI). Also known as the Bentler-Bonett normed fit index.	NFI equals the difference between the chi-square of the null model and the chi square of target model, divided by the chi-square of the null model. It is a relative fit measure.	The fit index varies from 0 to 1, where 1 is ideal. NFI of .90, for example, indicates the model of interest improves the fit by 90% relative to the null or independence model.
PRATIO.	Parsimony Adjusted Fit Measure. Model complexity is taken into account. Fit is typically improved by adding more parameters to the model. This measure penalizes for complicating the model.	Generally values above 0.5 are considered good.
AIC is an information theory goodness of fit measure.	Applicable when maximum likelihood estimation is used.	The absolute AIC value is irrelevant, although values closer to 0 are ideal; only the AIC value of one model relative to the AIC value of another model is meaningful. Compare the default model to the saturated, independence and zero models.
GFI a classical goodness of fit measure.	Absolute fit measure. Proposed as analogous to R^2 in regression (Blunch, 2008).	The fit index varies from 0 to 1, where 1 is ideal.
RMR is an absolute fit measure.	Root mean square residual.	Usually less than 0.05 is a sign of good fit.
Relative chi-square $\chi^{\wedge 2}$/df. Also called the normed chi-square.	Equals the chi-square index divided by the degrees of freedom for the model. Sample size dependent. Absolute fit measure.	Reports range from less than 2 (Ullman, 2001) to less than 5 (Schumacker and Lomax, 2004). Least desirable fit statistic due to known problems (Hoyle, 1995).

D. Survey Development

To validate prior theory, the survey instrument was developed according to the success factors reported from the Khurana and Rosenthal (1997; 1998) research, while taking into account other reported findings for the front-end construct. The survey developed for this research was subjected to reliability and validity testing prior to the main data collection.

The instrument for this research at the project level was created by applying survey development best practices as described by Churchill (1979). First, the literature was reviewed to specify the construct domain. Chapters 2 and 3 presented the literature review and the research statement that specified the intended domain for the research. Table 3.1 included the summary of the key references used to generate sample survey items. In addition, suggestions by Fowler (1984), as well as those from Nunnally and Bernstein (1994), were used for developing the items for the instrument using Likert scales. The pretest survey was reviewed and approved by the University Institutional Review Board. A copy of the approval is given in Appendix A. Construct validity analysis was completed to assess the measures by subject experts. The items were adjusted based on expert feedback. A pretest study was conducted to collect data based on actual NPD projects from respondents working in industry. The pretest data was used to measure instrument reliability and validity. The survey instrument was then adjusted, and rechecked by subject experts before the main data sample collection. Following main data sample collection, the survey was then again tested for reliability and validity. Statistical analysis followed to test the hypotheses of the research model and develop the norms.

E. Survey Grammar and Content Validity Reviews

The survey grammar and construct content validity were evaluated in three cycles. The reviewers ranged from those checking the survey for grammar, to authors or academics in the field of NPD and psychometrics, to practitioners in the field of NPD. The sample size for the content validity review and methodology was consistent with prior research (Markham and Griffin, 1998; Tzokas, Hultink, et al., 2004).

The first cycle was an initial check by three reviewers. Their inputs were used to improve grammar and general formatting. The second cycle was completed by nine subject matter experts (SME) in the academic areas of new product development and psychometrics and experienced practitioners in product development. The purpose of this review phase was to assess the item content relevance to the construct being measured. Some of the participants were personally known to the researcher through university contacts, academic conferences, professional society meetings, or working relationships. Others were found through the literature and were requested to participate. The raters were provided a copy of the test instrument, a one-page abstract of the study, the conceptual model diagram, and the construct definitions with key references. A copy of the invite letter to the SME's is available in Appendix B. The SME's were instructed to score their agreement that the item in fact would measure the defined construct. Each item was scored on a 7-point Likert Scale from "strongly disagree this item measures the construct" to "strongly agree this item measures the construct." For each item there was an open-ended comment box. The survey was evaluated from the reviewers via either a paper-based or web-based instrument.

Reviewers for the second cycle helped to separate items measuring multiple dimensions, eliminate items not measuring the intended construct, eliminate duplicate items, and to better align item wording to the construct definitions. As one example of the feedback received, in the Khurana and Rosenthal (1997; 1998) product definition construct, their term is worded as, “preliminary market and technical assessment.” The observation was that the conjunction could cause interpretation bias. The item was thus split into two separate items based on consistent input from multiple reviewers.

After the pretest a third cycle was performed with seven different SME’s to validate the improvements. Following this third cycle, there was agreement on all items to the construct definitions which were provided. Appendix B contains the reviewer experience and background from each cycle. The survey was then used in a pretest study.

F. Pretest Study Survey Instrument

As the survey was developed specifically for this research, this section explains the survey in detail for the reader. For most questions a summary format is shown here. For the fully formatted survey, please see Appendix C.

The pretest survey was administered using a publically available online survey tool and was set up with multiple entry pages. The first page of the survey instrument included pre-screen questions. As in Markham (1998), there were certain criteria that determined a project’s suitability for this study. These criteria were designed to ensure the respondent and the organization fit with the objectives for the study. The initial items are shown in Table 4.2. Item 1 ensured that the organization was in fact involved in the development of new products. A definition to clarify the range of applicable new products was included with the question. An answer of “no” or “do not know,” excluded the respondent from further entries.

Table 4.2 Survey Items

1. Is your organization, business unit, or group involved in new products?
Examples of a New Product can be: a service offered, an internal product or process, an end consumer product, or a business-to-business product.
Answer Choices: Yes No Do Not Know

2. Does your organization use a phase-gate like project review system for new product development? Note: Phases or Stages of New Product Development may be rigid or loosely applied in your organization. May also be called milestone reviews.

Do Not Know	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**

3. The questions to follow are related to a new product you are working on now or have worked on in the past. The product may be one that was a success, or one that was not successful. The product may have already been released to the market OR the project may be in progress now. Please enter a name (or code) that will remind you of the product development project for which you are answering.
Open ended answer

4. Which of the following most accurately describes your involvement on this project?
Choices: **Project Sponsor, Project or Program Manager, Project Team Member, Functional Manager, Other, please specify ______**

5. In a few words, please tell us a little about this product. Ex., is it an internal product, a business to business product, an end-consumer product. It is a consumer good, an IT product, a medical device, an electronic product, a service, etc.
Open ended answer

6. What is the approximate status of this project?
Complete means product has been released to the customer. Customer can be internal or external to your organization.

Do not Know	0-25% complete	26%-50% complete	51%-75% complete	76%-99% complete	Complete	Cancelled before completed

Table 4.2 Survey Items (continued)

7. Where is this product within the general segments of the product development cycle? *(Definitions and figure were provided, see Appendix)* Front-end   Development   Market Launch   On the Market Already
8. This product development project was (or is expected) to be: Do not know   Highly Unsuccessful   Unsuccessful   Somewhat Unsuccessful   Somewhat Successful   Successful   Highly Successful
9. Please answer the following questions in relation to the product development project you entered. This product is "New-to-the-World." This product is "New-to-the-Company." This product is a "Product Improvement." This product is an "Addition to an Existing Product Line." This product is a "Cost Reduction." This product is a "Repositioning."

Item 2 ensured that the organization used a phase-gate project system. Consistent with the Khurana and Rosenthal (1998) research, the projects for the study had to be from organizations that had an existing phase-based product development process. Since it has been shown that most organizations have implemented a phased type process (Adams, 2004), this was not a difficult hurdle. A definition was provided, as organizations may use different terminology. Only those responses on the agree side of the scale were considered for analysis. Item 3 asked for a particular name for the project, while not necessary for analysis, this was the name used for possible follow-up interviews with the respondent. Item 4 was to determine their role with respect to the project. Item 5 requested a brief description of the product.

The status of the project in terms of percent complete and status within the NPD phases was captured in items 6 and 7. First, any project submitted had to have already completed the front-end segment. Second, the choices were evaluated for consistent responses, for example, it would be questioned if the project was marked in the 75%-99% complete range, but noted as still being in the front-end phase. With item 7, a link was included to a definition and figure of the development segments. The definition and picture was included because it was acknowledged from the review of the NPD process models, as well as the input from the survey subject reviewers, that the understanding for segments of the development funnel are not universal.

Item 8 measured the general overall success of the product as well as the innovation level, respectively. It is important to note that the later items measuring particular dimensions of success were not visible to the respondent at this point of the web-based survey. The product innovation level categories in item 9 were used directly as given in the Product Development Management Association (PDMA) 2003 Comparative Performance Assessment Survey (CPAS) (Adams, 2004) which were described in the literature review chapter.

The survey items for the research constructs were based on an 7 point Likert-type scale of strongly agree, agree, somewhat agree, neutral, somewhat disagree, disagree, strongly disagree, with an option for 'do not know.' Each individual item was scored on the scale. The "do not know" choice was included to give the respondent an explicit choice for each situation as it was important to know if the respondent was aware of the activity being measured. Alternatives to the "do not know" choice were considered for the survey design. The survey could have allowed respondents to skip questions, which may have resulted in missing values. The survey could have forced the respondents into choosing a response on the agreement scale or included a choice of not applicable (N/A). The research on including a “do not know” response on psychometric scales was consulted. Friedman and Amoo (1999) noted that providing a "don't know" choice significantly reduced the number of meaningless responses. After discussion with those versed in psychometric testing, as well as the NPD professionals who reviewed the survey, advantages of including the “do not know” response outweighed the difficulties for analyzing such responses. The data analysis plan was to not include a response when more than two items were marked “do not know” on any individual construct, or when a single respondent answered more than six items with “do not know.” The responses with the allowable percent of “do not know” answers would be analyzed as missing data (Roth and Switzer, 1995; Switzer, Roth, et al., 1998). The procedure will be explained further as part of the pretest data analysis section. For the main study, the analysis as missing data as well as imputed scores as recommended by Schafer and Graham (2002) will be discussed in a later section.

Table 4.3 provides the survey questions for the success dimensions. These questions began on page 2 of the web survey so as not to bias the respondent’s overall project success score on question 8. The “back” button was disabled on the web-based survey. The use of subjective measures, as noted in the literature review chapter, is typical of NPD research and allows comparison across different projects. Additionally, not all respondents would have access to actual information such as specific financial dollar amounts or direct customer measurement. The items covered the success scale from multiple dimensions to provide additional resolution over just item 8 which measured overall success.

Table 4.3 Survey Items Success Scale

10. Please answer the following questions in relation to the product development project you entered. This product: • Offers a number of benefits to the customer. • Satisfied (or is expected to satisfy) the Customer. • Met (or is expected to meet) the intended Competitive Advantage. • Met (or is expected to meet) the intended Technical Performance. • Met (or is expected to meet) the Financial objectives. • Met (or is expected to meet) the Time to Market objectives. • Met (or is expected to meet) the expected preparation for future products and strategy enhancement. • Met (or is expected to meet) the project schedule. • Met (or is expected to meet) the project budget. • Met (or is expected to meet) the project scope.

The third page of the survey included the front-end construct questions (Table 4.4). Question 11 consisted of 4 items to measure the new product strategic fit. The first item covered the alignment of the project to organizational strategy. Items two and four were consideration of the project as part of the portfolio and the respective ranking. Item three questioned the balancing of risk as part of the product strategy. Question 12 consisted of five items to measure product definition. The first item looked at the perception of overall product definition. Three items measured the product definition with respect to the three dimensions of market, technology, and customer. One item, which was reversed scored on the pretest survey, measured the assessment of prioritizing product features.

Question 13, consisting of 5 items, measured the front-end project definition construct. These items were to measure project based attributes as opposed to the product based attributes of question 12. The items measured both the technical and market contingencies, engineering and manufacturing skills, and resource allocation planning. Question 14 measured the organizational roles construct during the front-end. The attributes identified for this critical success factor covered a project manager role, a defined team, executive sponsorship, and delivery of communication.

Table 4.4 Summary of Survey Items for Front-End Construct

11. For this product: (Please note the rating scale. The first box is "Do not Know.")
    - There is alignment between this product and the organizational strategy.
    - The product is considered as part of the product portfolio plan.
    - Balancing risks is part of our product strategy.
    - The project is ranked within the portfolio of projects.
12. For this product during the early front-end phase:
    - Product definition is well developed.
    - Product definition includes a market assessment.
    - Product definition includes a technology assessment.
    - Product definition includes a customer needs analysis.
    - There are **no** clear priorities for product features.
13. For this product during the early front-end phase:
    - Technical contingencies are planned.
    - Market contingencies are planned.
    - Our engineering skill is at the required level.
    - Our manufacturing / production skill is at the required level.
    - Resource allocation planning is considered.
14. For this product during the early front-end phase of the project:
    - There is a clear project manager role.
    - The project team is defined.
    - The project has executive sponsorship.
    - Organizational communication is delivered.

The fourth page of the survey included questions 15 and 16 to evaluate information processing at the firm level. The items are included in Appendix C. These items were originally included to validate the information processing theory of Jay Galbraith (1973; 1977).

Communication with Dr. Galbraith during the early phases of this research (Carbone, 2006), as well as through the literature review, uncovered no prior validation studies of the Galbraith information processing theory. It is important to note here that based on the learning from the pretest study, these items were not included in the main study for several reasons. First, the data from the pretest sample population did not reliably load on the theorized IPT factors. Appendix D includes the analysis and further discussion on the data. Second, the IPT construct did not directly relate to, or support, validating the holistic front-end of NPD as defined in the research statement. Third, these items are firm related and the study was intended to evaluate the project level. Removing these items from the survey allowed for a focused study specifically related to the critical success factors on the front-end and the corresponding impact on product success.

General questions and demographics were located on the final page of the survey to minimize any influence on the instrument itself (Appendix C). These questions were included to measure organizational attributes related to the product development in the firm, the respondent's number of years in NPD, information about the industry type, firm size, and business unit size. Question 26 asked for the respondent's function, which may or may not have been equal to the role they played on the project as asked in question 4. These items are consistent with the demographic questions from the PDMA CPAS Survey (Adams, 2004).

G. Pretest Study Data Collection

The sample for the pretest study were professionals involved within their organizations product development effort. For example, this included representatives from marketing, sales, product management, project management, and research and development. The main purpose of the pretest study was to validate the survey instrument. Data for the pretest was collected between August 2009 and October 2009.

A request was sent to chapters of the Project Management Institute (PMI) and the Product Development and Management Association (PDMA) to advertise the survey to their memberships. Some of the chapters published the link to the survey in their newsletter or emailed a link directly to their members. These professional societies were chosen based on the demographics of their membership, many of whom are involved in projects related to new products. The researcher had previously been invited to deliver chapter presentations about the research to the members of these organizations. Additionally, an email invitation was sent by the University of Alabama in Huntsville distance learning office to employed graduate students. A sample of the pretest introduction email is given in Appendix C.

H. Pretest Study Results

The pretest data was analyzed using PASW Statistics 18 (formerly SPSS) and JMP8 to test validity and reliability of the survey instrument. The online survey had a total of 104 responses, 65 of which were complete and valid for the pre-test. The 39 unusable responses were broken down into two groups. Of these, 28 were partial responses that did not complete all pages of the survey and were classified as drop-outs. The remaining eleven did not meet the do-not-know (DnK) response criteria which will be explained further in the analysis section.

I. Pretest Industry Demographics

There was a wide range in the industry distribution. Thirty-one percent of the responses selected defense related industries (Table 4.5). This is most likely attributed to the defense related companies in and around the Huntsville, Alabama area where many of the respondents were employed. Given the sample size from the pretest data collection, the data were not analyzed by subgroups of industries.

Table 4.5 Industry Distribution

Industry	Frequency	Percent
Advertising	1	1.5
Aerospace	12	18.5
Automobiles	3	4.6
Computers	1	1.5
Construction	2	3.1
Consulting	2	3.1
Defense	20	30.8
Education	2	3.1
Electronics	6	9.2
Energy	2	3.1
Health Care	3	4.6
Industrial	2	3.1
Materials	1	1.5
Not-for-Profit	3	4.6
Software & Computers	3	4.6
Technology & Telecommunications	2	3
Total	65	100.0

J. Innovation Level Analysis

As noted in the literature review, innovation level of a product may impact the processes used by organizations to manage new product development. The innovation level for 27 of the 65 (41%) submitted projects was originally classified as "new to the world" (NTW). NTW products are defined as the most innovative, radical, discontinuous, and complex NPD projects.

Past research on NTW products has shown these to represent under 10% of the realm of new products (Adams, 2004). The definition from Colarelli-O'Connor and Veryzer (2001, p. 233) for radical innovation is, "a product that creates a new line of business for both the firm and the marketplace." Based on the open-ended comments describing the products, many were from lower innovation levels when compared to the definition for NTW. Given the projects submitted and prior research on the percentage of products that truly are new to the world, it is likely the respondents evaluated innovation level more liberally than defined. The procedure and results to reconcile the selected innovation levels is given in Appendix D. Table 4.6 is the distribution of the innovation levels following the necessary corrections. A key learning around the innovation classification was that the product innovation level screen for the main study would require additional attention as the definition may not be universally known or understood. By controlling the main sample and better understanding the portfolio of products being submitted, the complexity of different innovation levels would be accounted for in future data collection.

Table 4.6 Innovation-Level

	Frequency	Percent
Additions to Existing Product Lines (AEL)	10	15.4
Product Improvements (IM)	15	23.1
New to the Company (NTC)	36	55.4
New to the World (NTW)	4	6.2
Total	65	100.0

K. Factor Analysis and Reliability

Given the various organizations responding and different levels of innovation, each front-end construct was analyzed individually for factor loading. This method of analyzing each sub-construct of the model is consistent with the NPD literature (Doney and Cannon., 1997; Spanjol, 2003; Atuahene-Gima and Wei, 2011). For the dependent scale of the success construct, all items were analyzed concurrently. The construct loading was obtained using a principal component method with a varimax rotation when necessary.

The responses for the Likert scaled questions were recorded as shown in Table 4.7, except for the reverse worded product definition scale item which was recorded in the opposite direction. The recoding was done as a matter of convenience for ease of interpretation and not necessary for the analysis.

Table 4.7 Likert Scale Coding

Value	Value Label	Recode
1	Do Not Know	Left Blank
2	Strongly Disagree	-3
3	Disagree	-2
4	Somewhat Disagree	-1
5	Neutral	0
6	Somewhat Agree	1
7	Agree	2
8	Strongly Agree	3

A response was not utilized for the data analysis if the respondent selected more than two items on any individual construct or more than six DnK's overall. As previously noted, the

DnK response choices were included to ensure the respondents were familiar enough with the project from the perspective of the research questions. There were 49 of the 65 usable respondents who answered 100% of the questions. Of the 16 respondents with included DnK responses, which met the criteria to retain, five noted their role as a project manager and the other eleven selected team member. The distribution of DnK by question and respondent is shown in Appendix D.

The component loading and reliability analysis summary is shown in Table 4.8. A more detailed statistical analysis for the factor loading, reliability, and descriptive statistics is given in Appendix D.

The new product strategic fit items loaded on one component and no rotation was necessary. All standard factor loadings were significant, which indicates good convergent validity (Cohen, 2002). The reliability of the scale was sufficient at 0.806. While item NPS-3 had a slightly lower loading than the other 3 items, and the reliability might increase slightly if it were removed, the decision was to retain the item.

The product definition items loaded on one component, with no rotation necessary. Item five contributed the lowest loading (0.517) and was the reversed worded question. While reverse scored questions are sometimes recommended in the literature, they are often noted as a point of confusion for respondents. The reverse worded question will be removed for the main study. The scale reliability was 0.815.

The project definition sub-construct items loaded on two components and rotation was necessary. Item PJ-2 measuring market contingency planning did not load with the other three items. In the original literature, and as noted previously during the survey development section, items PJ-1 and PJ-2, were written as a single item stated as, "technical and marketing contingencies are planned for." The loading difference could be because the marketing work is sometimes initiated before the project moves into project definition. Typically during project definition, a team will work on technical contingencies. For the main study, this will remain as two items to retest the theory from the literature. The scale reliability was 0.631.

Table 4.8 Pretest Factor Analysis and Reliability Summary Table

Front-end Constructs

	Component Loading		Scale Cronbach Alpha
New Product Strategic Fit			
NPS-1: Alignment	0.818		0.806
NPS-2: Portfolio plan	0.789		
NPS-3: Balancing risks	0.653		
NPS-4: Project is ranked	0.915		
Product Definition			
PD-1: Product definition	0.863		0.815
PD-2: Market assessment	0.755		
PD-3: Technology assessment	0.835		
PD-4: Customer needs analysis	0.856		
PD-5: Feature priority	0.517		
Project Definition			
PJ-1: Technical contingencies	**0.537**	**0.541**	0.631
PJ-2: Market contingencies	-0.043	**0.922**	
PJ-3: Engineering skill	**0.803**	0.177	
PJ-4: Production skill	**0.595**	0.377	
PJ-5: Resource planning	**0.799**	-0.246	
Organizational Roles			
OR-1: PM role.	0.876		0.859
OR-2: Project team	0.865		
OR-3: Executive sponsor	0.803		
OR-4: Organizational communication	0.822		

The organizational roles sub-construct items loaded on one component and no rotation was necessary. The reliability of this scale was 0.859. All items will be retained for the main study.

The pretest data was also used to assess the multi-dimensional aspects of success. As discussed in the literature review, success can be associated with the operational (internal) and/or market-based (external) success dimensions. The instrument used a 10 item scale to evaluate the multidimensional aspect of success. Based on the factor analysis, two components were extracted (Table 4.9). The first component was made up of the items: benefit to the customer (S1), satisfied the customer (S2), met competitive advantage (S3), met technical performance (S4), preparing for the future (S7), and met the scope (S10). All of these success measures, except met the scope (S10), are typically more associated with external performance measures and winning in the market place. Meeting the project scope is typically associated with operational measures. Depending on how respondents interpret the meaning of the term 'scope,' it may influence their association of this term. Scope is sometimes considered the meeting of performance based on the project dimensions of time, cost, and scope. However, scope to others may mean delivering to the customer what they asked for, when they wanted it, with the value they expected, thus as an external measure similar to meeting technical performance. Akgün and Lynn, et al. (2006) who used 10 measures for success removed the "met technical performance" measure after it failed to load with the other measures on their success construct. The item will be retained for the main study and is theorized to load on the internal construct when using a more homogeneous sample with similar innovation level projects.

The second component was comprised of the items: met the financials (S5), met time to market (S6), met the schedule (S8), and met the budget (S9). Based on the success measurement literature, the time to market, meeting of the schedule, and meeting the budget are typically associated with operational goals and objectives. The financial measure (S5) is typically associated with the market outcome, and it loaded opposite to expected. This was most likely impacted by the percentage of defense related responses in the sample.

Two respondents from defense company employees noted in the open-ended comments that they do not track financial success from projects. The overall reliability of the success scale was 0.918. There are no items that show a better scale composition if deleted. The detailed factor analysis, reliability, and descriptive statistics are given in Appendix D.

Table 4.9 Pretest Factor Analysis and Reliability Summary Table

Success Construct

Dimensions of Success	Component		Expected Dimension
	1	2	
S1: Benefits to the customer	**0.827**	0.052	External
S2: Satisfied the customer	**0.880**	0.274	External
S3: Met competitive advantage	**0.762**	0.299	External
S4: Met technical performance	**0.632**	0.501	External
S5: Met the financial objectives*	0.387	**0.690**	External*
S6: Met the time to market objectives	0.371	**0.822**	Internal
S7: Met preparation for future products / strategy enhancement	**0.637**	0.409	External
S8: Met the project schedule	0.246	**0.891**	Internal
S9: Met the project budget	0.130	**0.883**	Internal
S10: Met the project scope*	**0.641***	0.460	Internal*

* Loaded opposite to expected during the pretest.

L. Data Analysis from the Pretest

The various types of industries, some for-profit, some not-for-profit, and the variation in product-types in the pretest sample, posed a challenge to test the hypothesized model. Additionally, the sample of 65 responses was too small to utilize structural equation modeling. This was complicated by the missing data points. The pretest data was thus confined to validation and reliability testing of the survey instrument. The pretest nonetheless provided significant learning in preparing for the main data sample selection.

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M. Conclusions and Lessons Learned from the Pretest Study

The pretest study contributed to the research in the following ways. First, the survey was subjected to three separate review cycles. The reviewers contributed valuable comments on the survey design and content validity. Second, there was an improvement of the survey instrument with a research focus on the front-end construct and impact on success. Third, the survey was validated through confirmatory factor analysis methods and internal consistency.

While the pretest was valid for refinement of the survey, one of the main lessons learned was the importance of using a more homogeneous sample. The respondents to the pretest were from a general population and the products evaluated covered many types of industries. Adding to the complexity was the possibility that the innovation level definitions may not align appropriately for analysis between a wide range of industries. Additionally, some of the respondents were employed in not-for-profit and defense related organizations. A focus on specific levels of innovation within a singular industry was the objective for the main study. The pretest contributed to validate the survey instrument for the purpose of continuing to the main data collection phase of the research.

N. Main Study Introduction

With the survey validated during the pretest, the research proceeded to the main phase. This section first describes the main study industry characteristics. Second, the benefits and limitations of the chosen sample are discussed. Third, the survey instrument adjustments and modifications prior to the main data collection are explained. How the projects were selected and the survey distributed is covered in the fourth section. The fifth section introduces the procedures that will be utilized in Chapter 5 for the data analysis.

N.1. Main Study Industry Characteristics

As highlighted in the literature review, many prior studies contributed to the NPD body of knowledge through broad industry research encompassing various levels of innovation. Whereas the broad approach has provided key learning on success factors, other research has shown the need to focus on particular industries and like-levels of innovation in order to customize the NPD process for success maximization. This dissertation focuses on a high technology industry, with products at the new to the company, additions to existing lines, and improvement levels of innovation. The objectives are to test the prior reported critical success factors of the front-end of NPD and the corresponding impact on success. Furthermore, the dissertation uses a semiconductor company as a representative high technology company.

There have been previous studies of innovation in the semiconductor industry as part of a general research sample (Carbone, 2004; Spanjol and Beuk, 2007; Griffin, Price, et al., 2009) or as the sole focus (Thompson, 2000; Macher, 2001; Seah, 2002); however, none of these studies researched the front-end critical success factors on product success as described in this dissertation.

Semiconductors were one of the 14 industries classified by the North American Industry Classification System (NAICS) as Level I high technology companies (Hecker, 2005). Table 4.10 lists characteristics of a high technology industry with comparisons to the semiconductor industry.

In 2007, worldwide sales of integrated circuits surpassed total sales of $255.6 billion (Semiconductor-Industry-Association, 2008). In order to achieve that level of sales growth, the industry has continually invested in innovation for product development (Chatterjee and Doering, 1998). In 2008 the R&D and capital spending, as a percent of revenue, ranged between 7 - 35% and capital spending for 2011 will be more than $60 billion. While the barriers to entry are significant, there are high risks to many products being subject to changes in trends and technology advances. Semiconductor technology is quickly adapted for use in smaller, faster, less expensive products.

The high level of research spending in the industry is required to develop innovations through the integration of science and technology. High technology companies accounted for science and engineering employment that were at least five times the average and had 24 percent or more of industry employment (Hecker, 2005). The semiconductor industry has a number of initiatives for collaboration and advancement of the technology through the development of science and engineering employees.

Table 4.10 High Technology and Semiconductor Characteristics

High Technology Industry Characteristics	**Semiconductor Industry Characteristics**
High R&D High Capital Investment High Risk	• R&D and related engineering activities range from 7% to 35% (Walko, 2008). • Ranked as the industry that spends the most on innovation (Booz-&-Company, 2010). • Capital spending in 2011 was $60.4 billion (IC-Insights-Inc., 2011). • Products are subject to fashion trends adding to investment risk (Christensen, King, et al., 2008).
Fast Diffusion of Technological Innovation	• America's second-largest exporting industry in both total exports ($52 billion) and net exports ($25 billion) (Semiconductor-Industry-Association, 2008). • Semiconductors are found in everyday consumer applications from computers, smart phones, toys, appliances, and automobiles (Moris, 1996).
Fast Process of Evolution of the Applied Technologies	• Advances in microchip technology continue to drive higher productivity through faster, smaller, and cheaper technology. • The typical desktop PC system of 2007 was at least 100 times more powerful than the typical system of 1997, at about one-third the cost $630 vs. $1,833 (Semiconductor-Industry-Association, 2008). • Requires production of a large variety of products, each product in small volumes and each perhaps for only a short time, i.e. cell phones and MP3 players (Christensen, King, et al., 2008).
Demand of Science High Creativity Requirement for Teamwork	• One of the most knowledge-intensive manufacturing industries in the world (Macher and Mowery, 2003). • Semiconductor Industry Association member companies contributed more than $350 million between 2001 and 2006 to improve student achievement in grades K-12 science, engineering, and mathematics (Semiconductor-Industry-Association, 2008).

The organization selected for the main study provides a broad range of high performance semiconductor devices into multiple markets. The products are primarily used in consumer, communications, computer, and automotive applications with divisions organized for such markets. Design and manufacturing facilities are located around the globe. The revenue is between one and two billion dollars a year. The R&D percentage ranged between 7% to 9% over the past several years. In a surveys of the top 50 industry sales leaders the company was ranked within the 25th to 50th percentile (Arensman, 2007).

Several of the business units have been acquired through acquisition within the past decade. These purchases have enabled the organization to more quickly acquire new technology. More importantly for this research, these product lines operate semi-independently as autonomous business units. The products and technology are mainly developed by degreed engineers and scientists. Based on these characteristics, the company can adequately represent the semiconductor industry which is a representative of high technology.

N.2. Main Study Sample Benefits and Limitations

Organizing this research to focus on one large organization was not entered without significant considerations. As pointed out in the literature review, there are numerous prior studies covering multiple industries and product innovation levels. The corresponding success factors have in some cases been reported as common across industries. While there are critiques over single industry focused samples, there was opposing literature stressing the importance of more focused research needed for particular industries at particular levels of innovation. The importance of focusing research on a particular industry was made by Lawrence and Lorsch, "a set of marketing, manufacturing, and research policies that works well for a firm in the chemical industry will not meet the needs of a corporation producing steel" (1967, p.1).

Given the sample population described, the researcher acknowledges the following limitations as described by Campbell and Stanley (1963). Selection bias is acknowledged as those who responded to the survey were knowledge workers involved in new product development and can thus be considered to be interested in the subject. The sample chosen is thus a convenience sample in that the data collected was based on the respondents being available and their willingness to participate. The risk was accepted and acknowledged based on the research objective to study specific levels of innovation for semiconductor products. The methodology does not claim to measure the population at large. The results described must be interpreted with these limitations in mind, and that no claims are made in order to generalize beyond the context presented. The research aims at developing the norms of the front-end of product development for a specific level of product innovation within a single industry to counter some of the limitations of prior research as previously discussed. Furthermore, the participation in the survey was completely voluntary.

There is the threat known as recall, which relates to how valid and confirmable the data is from the respondents. This threat was mitigated as those selected were confirmed to be involved in a specific and recent project.

There is a threat for response bias if respondents from only certain regions or divisions were to respond. This was countered through a random sample which could be verified and tested to ensure inclusion amongst divisions and regions of the organization.

The method could also be at risk from observer effects or location threat. Respondents could encounter attitudes that the survey was important to them professionally or personally. This was countered by highlighting that no actual respondent names or project names would be included in any of the data analysis or reports.

The research acknowledges these limitations. However, given the absence of prior research to validate the holistic front-end construct, coupled with the literature highlighting the importance of studying like levels of innovations and industries, it is proposed that the results will contribute to the body of knowledge.

N.3. Survey Modifications Prior to the Main Data Collection

The survey was shortened for the main sample data collection as some of the antecedent items were known through observation. First, the organization under study for the main sample has been using a phase-gate model for product development for several years. Second, based on the lessons learned from the pretest and the literature recommendations, the main study was limited to like-levels of innovation. The lowest innovation level of cost reductions and the highest innovation level of new to the world products would not be considered. Third, how a company defines the lifetime of a new product impacts how new product revenue and success is measured. Depending on the industry, a new product may be counted as new from months to years. The sample company has set the life of a new product at three years. Fourth, as the sample was from a single large multinational company, made up of multiple divisions, the size of each was known in advance. Fifth, product type was controlled since all were semiconductor products even though the company serves various markets. The sixth antecedent, development time, can also impact how an organization structures the development process. For example, pharmaceutical development might take on the order of a decade while a semiconductor device could be on the order of months. The antecedents are thus controlled for in this study based on a similar set of projects for comparison which is in contrast to much of the prior literature which included a very broad base of industries, innovation levels, and company processes.

The first three questions collected baseline information about the project name, the respondent's role, and the project status. Question 4, about the status of the project within the stage-gate system, was reformatted from the pretest version. The link to the picture was removed and instead the definitions were included directly. Although the selection of projects was intended to screen out any projects not past the market launch segment, the answer choice remained in the question to validate the inputs.

The product definition construct items were slightly revised from the pre-test. The reverse wording for item PD5 was removed based on lessons from the pretest study. The item was now worded, "there are clear priorities for product features." Following modification, the survey was again reviewed and approved by the university Institutional Review Board. A copy of the approval form is given in Appendix A. The final version of the survey is included in Appendix G.

N.4. Main Study Project Selection and Distribution

The projects for the study were selected as follows. First, the population of products released within the prior two years was exported from the online information system. This was a modification from the pretest procedure in that only completed projects were included in this main sample. This was to obtain a more reliable measure of success. Two years was selected as the filter because the organization defines a new product as one that had been released to the market in the prior three years. The third year following release was not included because including it would have meant some new products might be past the defined "new product" definition point at the time of data collection. It was also a way to minimize the recall threat. A 50 percent random sample was generated from this population using a statistical computer program.

A second more deliberate method was initiated to collect information on projects that were not deemed an overall success. Interviews were conducted with the sponsors and development managers to collect a list of projects over the past three years that were not as successful as expected. This method, while certainly adding some bias, was countered by taking a random sample of the projects identified.

To select participants, the project schedule or deliverable signoff documents were used to identify the project manager, a team member, and either the direct sponsor or management member from R&D, marketing, or product engineering functions. The objective was to obtain at least two responses per project. In several of the cases, some of the identified project participants were no longer with the company and this initiated a second pass to find a project representative. By random selection of the projects, participants were random from various company divisions and geographical locations.

Once the projects and the participants were identified, a personalized request was sent by email to each individual. A copy of the invitation is given in Appendix F. The survey introduction page is shown in Appendix G.

N.5. Main Study Analysis Procedure

The data collected through the survey procedure was subjected to a confirmatory factor analysis (CFA) and reliability testing. The results were then analyzed to test the hypotheses presented in Chapter 3.

A response was not utilized for the data analysis if the respondent selected more than two items on any individual construct or more than six DnK's overall. The data from the included "do not know" responses were treated as missing unless otherwise noted. The DnK choices were inspected to confirm a random pattern.

The data was analyzed to compare successful projects against less successful projects. The success split was categorized based on the median from the items on the summated success scale. The projects were also categorized based on the respondents overall subjective success score. If a respondent's success scale score differed for the subjective measurement for the same project, the mean for the summated success scales was compared. The discrepancy was resolved to categorize the project as a successful or less than successful. This procedure is consistent with prior research analyzing new product comparison groupings (Song and Swink, 2009). Analysis was then completed to compare projects based on innovation level, regional response, project role, and years of experience in the new product development role.

Success analysis is multidimensional for this study. As explained in the literature review, there are prior studies which used a singular measure of success, with many based on a financial metric. In this study, success was measured on a multidimensional scale for the internal (operational measures) as well as the external (market-based) measures to counter some of the earlier shortcomings.

To test the hypotheses, the summated scale for each validated construct was used for the correlation analysis using multiple regression (Hair, Tatham, et al., 1998, p.116). The use of the summated scale reduces measurement error of single indicators and allows the representative of multiple items into one scale based on satisfactory factor analysis.

SEM analysis was run using the correlation matrix determined from the prior factor analysis. In order to run the SEM analysis, missing data was imputed using the mean for the individual response for the specific scale. While there are a few ways to deal with missing data such as pair-wise deletion or a way of substitution, the replacement with the mean had a low risk and allowed to analyze the most complete data set. There were very few responses with missing data. A total of 18 choices out of the 4256 (0.42%) were selected as DnK. This low percentage introduced negligible risk to using an imputed mean as compared to the value from insights to the model by using SEM. For a more comprehensive treatment of SEM, the reader is referred to the references (Hoyle, 1995; Hair, Tatham, et al., 1998; Byrne, 2001; Blunch, 2008).

O. Summary

In this chapter the research method for the dissertation was reviewed. The methods for analyzing the data with various multivariate statistics were described. The survey development process was reviewed. The pretest study included responses from a number of industries and product types. Overall the survey was shown to be valid and reliable for the constructs of the theory based on this sample. Lessons learned from the pretest were used to revise the survey prior to the main data collection. The main data sample population was described with both limitations and benefits. Finally, the main sample project selection and analysis procedures were summarized.

CHAPTER V

DATA ANALYSIS

A. Introduction

This chapter covers the analysis of the respondent data from the main sample. The results from the data collection process are described. The chapter covers the instrument factor analysis and reliability statistics. The model is tested using a multiple regression model and structural equation modeling. The support for the hypotheses is described with discussion related to the theory.

B. Instrument Distribution

The survey was hosted on a commercial internet site. The data for the main sample was collected between July 2010 and September 2010. As previously noted in the methodology chapter, the survey was distributed to employees in various product groups in a global company. The survey responses were independent and relied on the respondent's direct experience with the project that was randomly chosen from available projects in the database. Contacts were found through the company's project information system which contains project deliverables and resource information. The associated names were most often found from either the project charter or the project schedule.

A few respondents had to be reminded by email to complete the survey. This was partly because data collection occurred during the summer vacation season. In two instances, the participants contacted the researcher and asked to evaluate a different project than the one provided through random selection. The root cause was that the participants wanted to evaluate a project that was 'more successful' in their opinion than the one identified through the random sampling. The researcher explained the intent of the study, and that it was best to use the randomly selected project. The participants then agreed to use the originally selected project.

Throughout the process, the confidentiality of the results was emphasized. The respondents were reminded that the researcher would not link individual names to the responses. Additionally, it was required that the actual project names would not be disclosed outside the performing organization, nor would the specific organization be identified outside the researcher and the committee members.

C. Response and Demographics

The response rate to the survey was over 95% with 152 valid responses. This is not typical of reported survey response rates which more often range from 10% to 40%. There were a couple of reasons attributed to the strong response. The requested respondents likely recognized the sender of the email request. The email being sent through the company mail system could have driven more interest versus a request from an 'outsider' for a survey response. The demographic distribution is shown in Table 5.1.

For the 152 responses, there were 63 distinct new product projects in the sample. The sample size is consistent for success/failure comparisons based on a research using the survey method (Zirger and Maidique, 1990; Ottum, 1994; Langerak, Hultink, et al., 2008).

The product groups responding reported into either major division A or B with 80 and 72 responses, respectively. The respondent years of NPD experience ranged from under 5 years to over 25 years with 54% of the respondents having between 6 and 15 years experience in product development.

The respondent's role for the new product project was categorized as project manager, team member, or project sponsor. The project manager is the employee designated to lead the project. The team member role is someone who is assigned to the core project team from the beginning to the end of the project. Their functional role may originate in the design, test, marketing, or similar functions. The project sponsor role is a key stakeholder from product line, marketing, or R&D management.

As the projects were randomly selected and team members were globally located, their home country was collected. The submissions from company sites within the U.S.A. accounted for 46.1% of the responses. The overseas locations in Asia account for 53.9% of the responses.

Table 5.1 Demographic Data Summary

Company Division	Total	% of Total
A	80	52.6
B	72	47.4
Years Experience	**Total**	**% of Total**
5 or less	53	34.9
6 – 10	62	40.8
11 – 15	20	13.2
16 – 20	13	8.6
21 – 25	3	2.0
over 25	1	0.7
Project Role	**Total**	**% of Total**
Project Manager	64	42.1
Team Member	54	35.5
Project Sponsor	34	22.4
Region	**Total**	**% of Total**
U.S.A.	70	46.1
Asia	82	53.9

D. Front-end Construct Factor Analysis and Reliability

The factor analysis was completed based on all items for the front-end construct analyzed in a single grouping. Table 5.2 is the summary of results from the principal component varimax rotated factor solution. The theorized four components were extracted with general item agreement except in the following cases. Item PD-1, "product definition is well developed," was not strongly associated with the other items that loaded on the product definition construct. The item cross loaded with higher scores on two of the other extracted components, but it was not strongly associated with any component. Given the possible weakness in this item, it was dropped prior to analysis.

Table 5.2 Front-end Construct Factor Loading Summary

Construct Items	Component				Scale Alpha
	1	2	3	4	
New Product Strategic Fit					
NPS-1: Alignment	0.232	**0.827**	0.153	0.153	0.817
NPS-2: Portfolio plan	0.149	**0.805**	0.163	0.189	
NPS-3: Balancing risks	-0.010	**0.789**	0.156	0.166	
NPS-4: Project is ranked	0.391	**0.655**	0.190	-0.172	
Product Definition					
PD-1: Product definition	**0.389**	0.207	***0.478***	***0.435***	0.836
PD-2: Market assessment	**0.821**	0.177	.209	0.070	
PD-3: Technology assessment	**0.696**	0.172	0.038	0.322	
PD-4: Customer needs analysis	**0.874**	0.123	0.088	0.056	
PD-5: Feature priority	**0.523**	0.058	0.180	0.430	
Project Definition					
PJ-1: Technical contingencies	0.274	0.081	-0.134	**0.790**	0.774
PJ-2: Market contingencies	***0.788***	0.063	0.128	0.296	
PJ-3: Engineering skill	0.305	0.112	0.475	**0.620**	
PJ-4: Production skill	0.125	0.099	0.337	**0.671**	
PJ-5: Resource planning	0.095	0.195	0.313	**0.537**	
Organizational Roles					
OR-1: PM role	-0.096	0.491	**0.605**	0.215	0.811
OR-2: Project team	-0.002	0.310	**0.683**	0.329	
OR-3: Executive sponsor	0.329	-0.002	**0.801**	0.030	
OR-4: Organizational communication	0.207	0.316	**0.757**	0.136	

N = 143, nine excluded for do not know responses.

Item PJ-2 for the planning of market contingencies on the project definition component had a loading of 0.296 and was more closely aligned with component 1 for product definition. This item also suffered from a low loading during the pre-test. This is further evidence that market contingencies may not be typically associated with part of the project definition work, but rather with the product definition. Based on an understanding of the organizational process for this organization, there is observational data to support this possibility. Definition of the product and market usually happens separately from the early project definition work for planning and resourcing. However, recently within the organization, criteria have been initiated to integrate market contingency planning within the development of the project plan. Given the possible weakness in this item, it was dropped prior to the analysis. The CFA was re-run with the items PD-1 and PJ-2 removed. It was confirmed that four components were again extracted with adequate loadings on the proposed constructs.

There were two items with cross-loadings on two components with scores greater than 0.4 and a difference less than 0.2 from the highest loading component (Anderson, Plotnikoff, et al., 2004). With all factor analysis, final determination on which items to retain is admittedly often subjective. Item PD-5 loaded at 0.523 on component one, but at 0.430 on component four, for a difference of 0.1. Similarly, item OR-1 loaded on component four at 0.605, but at 0.491 on component three, for a difference of 0.1. As in other factor based research given the theory, the high primary component loadings, and the scale reliability, these two items were retained in order to not sacrifice content validity of the scale (Podsakoff, Ahearne, et al., 1997; Anderson, Plotnikoff, et al., 2004).

For the analysis the "do not know" (DnK) responses were treated, as in the pretest, as missing data when meeting the prescribed criteria for inclusion. There were only 18 DnK selections across nine of the 152 respondents in the main data sample which is significantly less than in the pretest data sample. This is likely because the product development process terms are less ambiguous within a single organization. For the questions with a DnK choice, there was no specific noticeable pattern across the matrix of questions or by respondents. The factor analysis was also run by imputing the DnK responses with means replacement, and there was no change in the component loading and the scores were essentially unchanged. The distribution for the DnK's is shown by question and response in Appendix H.

As noted in the methodology chapter several factor analysis measures were evaluated as recommend by (Hair, Tatham, et al., 1998). The correlation matrix was inspected for patterns of relationships and to determine sufficient correlation (greater than 0.30). The determinant of the correlation matrix was calculated to be 3.06E-05. Values greater than 1.0E-05 are recommended to ensure multicollinearity is not an issue. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.87. Bartlett's test of sphericity was significant ($p<0.001$).

The scale Cronbach alpha was calculated for each sub-construct of the front-end with the corresponding values of 0.817 (NPS), 0.836 (PD), 0.774 (PJ), and 0.811 (OR). All constructs met the guidelines for acceptable item reliability. Appendix I contains the detail descriptive tables and matrices for the factor analysis and reliability.

E. Success Construct Factor Analysis and Reliability

The success construct loaded as theorized on two components that were distinguishable as the market-based (external) and the operational-based (internal) success measures. The market-based measures of success were benefits to the customer, satisfying the customer, met competitive advantage, met technical performance, met the financial objectives, and met preparation for future products. The operational measures of success were met the time to market objectives, met the project schedule, met the project budget, and met the project scope. Table 5.3 contains the summary results from the principal components varimax rotated factor solution for the success construct.

Table 5.3 Success Scale Summary Table

	Component 1	Component 2
External Success or Market-based Success		
S1: Benefits to the customer	**0.773**	0.137
S2: Satisfied the customer	**0.790**	0.291
S3: Met competitive advantage	**0.874**	0.097
S4: Met technical performance	**0.594**	0.382
S5: Met the financial objectives	**0.631**	0.458
S7: Met preparation for future products	**0.550**	0.027
Internal Success or Operational Success		
S6: Met the time to market objectives	0.363	**0.802**
S8: Met the project schedule	0.018	**0.926**
S9: Met the project budget	0.105	**0.896**
S10: Met the project scope	0.494	**0.675**

N = 150, two excluded for do not know responses.

For the main data sample items met financials (S5) and met scope (S10) loaded as proposed on the external and internal components of success, respectively. It is suspected that this loading is the result of the sample being more homogeneous than the pretest sample, in a for-profit organization, with fairly well understood organizational norms for the NPD process.

As noted in the methodology chapter several factor analysis measures were evaluated as recommend by (Hair, Tatham, et al., 1998). The determinant of the correlation matrix was calculated to be 0.003. Values greater than 1.0E-05 are recommended to ensure multicollinearity is not an issue. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.86. Bartlett's test of sphericity was significant ($p<0.001$). There were no cross-loadings with a difference less than 0.2.

The overall success scale reliability was 0.886. It was unnecessary to consider the removal of any items. The success scale factor analysis was also run by imputing the DnK responses originally treated as missing, there was no change in the component loading with the scores essentially unchanged for all practical purposes. Details from the factor analysis and reliability testing are reported in Appendix I.

As the items developed for this survey were based on prior existing theory, and given the acceptable factor loading along with the scale reliability, for both the pretest and the main sample, it was concluded that the instrument was valid to measure the proposed holistic front-end model for the objectives of this research. The next session covers the analysis of the data from the main sample.

F. Success Analysis

There is inherent and acknowledged challenge in measuring and quantifying project success. Subjectively there can be disagreement on what determines a project is a success or not. Therefore, ten items measuring components of success were included and compared to a single overall subjective measurement. At the project level, there were only four project cases where there was disagreement on the subjective scale between respondents. In these cases, means tests were used to compare the scale means for the 16 front-end component items, as well as the 10 success scale items combined (by small sample t-test). In either case there was no difference in the mean. The summary is show in Table 5.4.

As in Song and Swink (2009), the success and less successful split was taken at the median value, which here was 1.0 on the subjective success score. The project coded in the table as "B" was thus assigned to the 'less successful' category. It is worth noting that the category of 'less successful' is being instead of 'not successful.' Although the scoring may have been towards the "not as successful as expected" side of the scale, it would be presumptuous to classify the projects as not successful given the relative nature of success.

Table 5.4 Project Success Reconciliation

Project (arbitrary code)	Role	Respondent Subjective Score	p-value	Success Scale Means	Final Determination for Project
A	PM	Less Successful	0.66	1.8	Success
	Sponsor	Success		2.1	
B	PM	Less Successful	0.55	0.3	Less Successful
	TM	Success		0.9	
C	PM	Success	0.09	1.9	Success
	TM	Success		1.9	
	Sponsor	Less Successful		1	
D	PM	Less Successful	0.98	1.2	Success
	TM	Success		1.3	
	Sponsor	Less Successful		1.3	

Following the four reconciliations as explained above, there were 84 responses with projects marked as successful as expected and 68 responses as less successful than expected based on the singular subjective success item. The success distribution was further explored based on the multi-dimensional success measures. Based on the median of the external success scale, there were 77 responses with projects noted as successful as desired and 74 noted as less successful. Based on the median of the internal success scale, there were 85 responses with projects noted as successful as desired, and 66 noted as less successful. This distribution is shown in Table 5.5.

Table 5.5 Distribution of Success based on the Three Scales

	Subjective Success (1 item scale)	External Success (6 item scale)	Internal Success (4 item scale)
Successful	84	77	85
Less Successful	68	74	66

The mean and standard deviation based on each construct for the successful and less successful projects are given in Table 5.6. The mean values show the relative difference between the success and less successful scales. As noted in Table 4.7, the Likert scale ranged from -3 to +3. While the less successful projects had a lower mean on each variable, only the internal success variable had a mean less than zero. This demonstrates the importance of multi-dimensional measures of success that will be discussed further in the analysis.

Table 5.6 Success Descriptives by Construct

Construct Variable	Successes		Less Successful	
	Mean	Std. Dev.	Mean	Std. Dev.
New Product Strategic Fit	1.63	0.81	0.81	1.17
Product Definition	1.64	0.97	0.12	1.05
Project Definition	1.76	0.59	0.55	0.99
Organizational Roles	1.99	0.73	1.09	1.14
External Success	1.65	0.63	0.06	1.06
Internal Success	1.80	0.72	-0.40	1.46

G. Control and Demographics Analysis

The use of a phase development process was controlled for the main sample. Groups in the company use the same framework for their new product development process, although the specifics and degree of formality vary. The company size and industry was controlled based on the sample selection. The product innovation types submitted were 40 addition-to-existing-lines (AEL) projects, 62 new-to-the-company (NTC) projects, and 50 product-improvements (IM) projects. Table 5.7 contains the descriptive statistics for the success factors by innovation level. There was no statistically significant difference for the external success scale by innovation type ($p=0.24$). There was a statistical difference based on innovation level for the internal success score ($p<0.001$). NTC products had a statistically lower internal success mean (0.33) as compared to the AEL (1.55) and IM

(0.86) means. The difference is also managerial significant in that more innovative products may need to be treated differently than less innovative projects when it comes to schedule, budget, release timing, and scope planning. The NTC types of products, by their very nature are different than the AEL and IM projects, which impacts the budget, timing, and scope aspects of these projects. Likewise, if the product is new to the company, there may be conscious choices made to sacrifice internal success dimensions in order to secure future success on the external dimension. Innovation level is used in the analysis section as a moderating variable to test the research hypotheses described in Chapter III.

Table 5.7 Descriptive Statistics by Innovation Level

Innovation Levels	Number	External Success*		Internal Success**	
		Mean	Std. Dev.	Mean	Std. Dev.
Addition to Existing Lines (AEL)	40	1.01	0.89	1.55	1.20
New to the Company (NTC)	62	1.10	1.21	0.33	1.57
Product Improvements (IM)	50	0.73	1.26	0.86	1.59

The comparison for innovation level was also analyzed by each of the front-end constructs of new product strategic fit, product definition, project definition, and organizational roles. The statistical comparisons are in Appendix J.

Only the organizational roles (OR) construct was statistically different across the innovation levels (p=0.0001). The AEL projects with a mean of 2.19 on the organizational roles factor are observationally typically the most structured for teams and the project process. In comparison, the NTC projects with a mean of 1.53 are sometimes slightly more chaotic during the front-end segment and have a wider span of autonomy when it comes to team structure and project communications. On NTC projects, the project manager role is often filled by an engineer or technologist, especially in the early segment of a project. On the other end of the spectrum, product improvements with a mean of 1.18 are a lower level of innovation and are often structured less formally. There are likely lessons to be learned if the organizational role assignments are more formally compared for the level of product innovation.

The analysis by project role for overall success, external success, internal success, new product strategic fit, product definition, project definition, and organizational roles showed no significant difference (Appendix J). There was no significant difference between internal or external measures of success based on years of experience involved in NPD ($p=0.48$). Statistical tables and ANOVA analysis for the control and demographic variables can be found in Appendix J.

H. Variable Correlations

Based on the summated scales, the construct correlations are reported in Table 5.8. All correlations were significant ($p \leq 0.0001$). Values in parenthesis are the squared correlation to show effect size. The product definition scale was more strongly correlated with the external success scale, while the project definition was more strongly correlated with the internal success scale. The new product strategic fit (NPS) scale had a similar correlation for both external and internal success. The organizational role scale (OR) was also similar in terms of correlation and effect size between the external and internal success dimensions. A scatterplot matrix with density ellipses for the factors, the pairwise correlations, and the confidence intervals are given in Appendix K.

Table 5.8 Correlation Matrix

	External Success	**Internal Success**	**NPS**	**Product Def.**	**Project Def.**	**Org. Roles**
External Success	1					
Internal Success	0.56 (0.31)	1				
New Product Strategic Fit NPS	0.46 (0.21)	0.43 (0.18)	1			
Product Def (PD)	0.71 (0.50)	0.37 (0.14)	0.40 (0.16)	1		
Project Def (PJ)	0.47 (0.22)	0.60 (0.36)	0.36 (0.13)	0.50 (0.25)	1	
Org. Roles (OR)	0.52 (0.27)	0.50 (0.25)	0.51 (0.26)	0.41 (0.17)	0.53 (0.28)	1

I. Analysis of Hypotheses

Regression models were utilized to test the hypothesized relationships. The regression analysis was run using JMP8. The two success factors were run as the dependent variables and the four front-end variables as the independent variables.

The first regression model was run to test the effects of the four front-end variables on the external (market-based) success to test hypotheses H1a, H2a, H3a, and H4a.

> H1a: New Product Strategic Fit (NPS) is positively related to the new product project success from an external perspective.

H2a: Product Definition is positively related to the new product project success from an external perspective.

H3a: Project Definition is positively related to the new product project success from an external perspective.

H4a: Organizational roles are positively related to the new product project success from an external perspective.

The equation parameters and model statistics are given in Table 5.9. The residual plot and statistical data tables are given in Appendix L. There was partial support for the hypotheses. The Product Definition (PD) ($p<0.0001$) and the Organizational Roles (OR) ($p=0.0021$) variables were significant in the model. The null hypotheses were rejected for H2a and H4a. Therefore there is support for the positive relationship between product definition and organizational roles on new product success from an external perspective. The product definition variable had the strongest relationship. Product definition in the literature review was shown to be critical to satisfying the needs of the customer which surely has an impact on market success.

In the full factorial model, organizational roles were significant when crossed with product definition and project definition ($p=0.031$). All other cross terms were not significant. The assignment of a project manager, having a core team, executive sponsorship, and issuing organizational communication can thus be considered enablers during the front-end when considering organization for product and project definition.

New product strategic fit (NPS) and project definition (PJ) were not significant in the model. Therefore the null hypotheses for H1a and H3a failed to be rejected. This is partially explained based on the items on the NPS scale, which deal with internal processes for ranking projects and organizational alignment. These attributes would likely be more associated with internal success than external success. Project definition is certainly less connected to the specifics of defining the product and what the market would consider as value-add, which can explain these results.

Table 5.9 Effect of Front-end Variables on External Market-based Success

	Coefficients Parameters - Unstandardized	Std Beta	p-value
Constant	-0.144	0	0.2585
New Product Strategic Fit (NPS)	0.125	0.114	0.0954
Product Definition (PD)	0.534	0.575	**<0.0001****
Project Definition (PJ)	0.002	0.001	0.9833
Organization Roles (OR)	0.257	0.228	**0.0021***
R^2	0.582		
Adjusted R^2	0.570		
F-value	46.35		**<.0001***
N	138		

The second regression model tested the effects of the front-end variables on the internal (operational-based) success to test hypotheses H1b, H2b, H3b, and H4b.

H1b: New Product Strategic Fit is positively related to the new product project success from an internal perspective

H2b: Product Definition is positively related to the new product project success from an internal perspective.

H3b: Project Definition is positively related to the new product project success from an internal perspective.

H4b: Organizational roles are positively related to the new product project success from an internal perspective.

The equation parameters are given in Table 5.10. The residual plot and statistical tables are given in Appendix M. There was partial support for the hypotheses. The new product strategic fit (NPS) ($p<0.05$) and the project definition (PJ) ($p<0.0001$) variables were significant in the model. The null hypotheses were rejected for H1b and H3b, respectively.

Table 5.10 Effect of Front-end Variables on Internal Operational-based Success

	Coefficients Parameters - Unstandardized	Std Beta	p value
Constant	-0.822	0	<.0001
New Product Strategic Fit (NPS)	0.299*	0.201	**0.0124***
Product Definition (PD)	0.019	0.015	0.8517
Project Definition (PJ)	0.669**	0.426	**<.0001***
Organization Roles (OR)	0.248	0.162	0.0576
R^2	0.428		
Adjusted R^2	0.411		
F-value	25.050**		**<.0001**
N	139		

For the relationship to internal success, the product definition (PD) and organizational role (OR) variables were not significant in the model. Therefore the null hypotheses for H2b and H4b failed to be rejected. The results show that new product strategic fit and project definition had a greater impact on the internal success variables than did the product definition and the organizational roles. The NPS items which considered ranking and relation of the project to the portfolio and strategy showed the relationship these activities have on internally based measures of success. The significance of the project definition variable supports the theory that project definition related activities lead to a higher level of internal success for time, cost, and scope. The organizational resources (OR) variable was managerially significant for internal success (p=0.0576). Running the same analysis based on a stepwise regression model, which does not include the contribution from the product definition variable, changed the significance of the organizational role variable to also be statistically significant at alpha of 0.05 (p-value of 0.04).

J. Structural Model for Front-end Variable on Success

To test hypotheses H5a and H5b, the front-end latent variable was tested for the relationship to product success. The sample size of 152 may be inadequate for using structural equation modeling (SEM) to test the model using the individual indicator items. This is similar to the sample size challenge faced by other researchers with a desire to analyze NPD relationships with latent variables and SEM (Langerak, Hultink, et al., 2008). Given the acceptable loading from the earlier CFA analysis, the measurement model was already verified. To test the structural model, an alternative method is to use the correlation matrix. This was the method employed for this analysis. Figure 5.1 is the model showing the relationships between the latent variable of the front-end and the dependent internal and external success variables. The regression weights are set to 1 on the indicated paths as required by the modeling to set a scale for unmeasured variables. The weight is typically set to 1 on the variable with the highest regression coefficient. In this case the weight was set to 1 on the PD to FE path. For reference, the full model depiction with all individual measurement items is given in Appendix N.

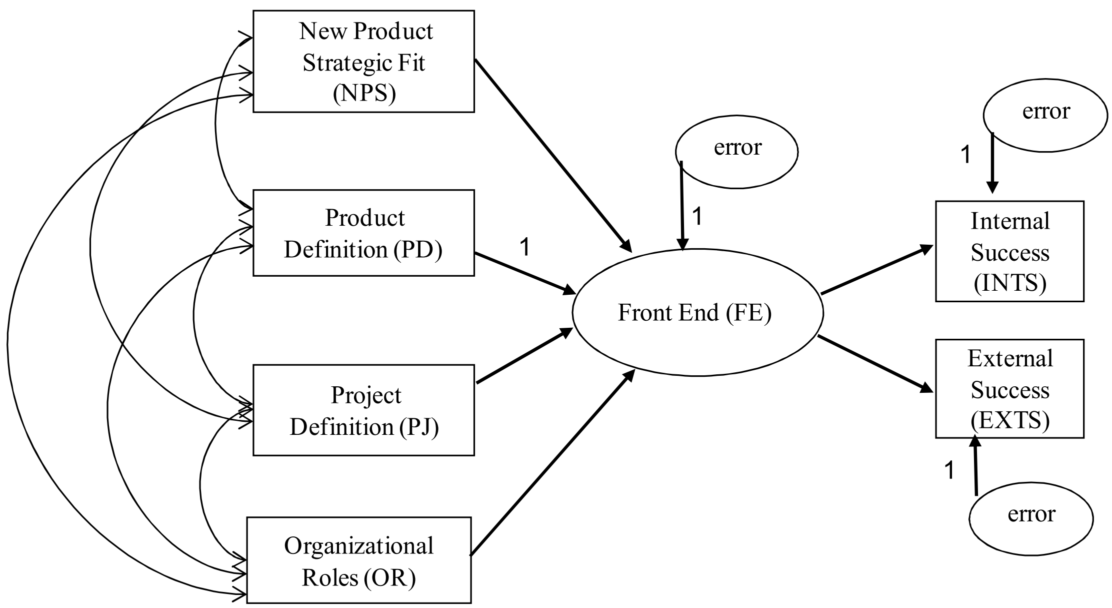


Figure 5.1. Structural Model

The hypotheses for this model are that the constructed latent variable of the holistic front-end, which was made up of the four front-end constructs (also latent variables), positively impacts success. Further, the impact on success was modeled for both the internal and external perspective.

H5a: Front-end critical success factor orientation is positively related to the new product project success from an external perspective.

H5b: Front-end critical success factor orientation is positively related to the new product project success from an internal perspective.

For both hypotheses (H5a and H5b) the nulls were rejected and there was support for the model with moderate fit. Figure 5.2 is the model showing the standardized regression weights and correlations. The regression weight of 0.64 along the path from the FE to internal success (INTS) was significant (p=.0001). The regression weight of 0.87 along the path from the FE to external success (EXTS) was significant (p=.0001). The regression weights for all paths are given in Table 5.11. All were significant at α=0.05, except PJ on FE which had a p value of 0.066. NPS on FE was significant at p=0.040. ORG on FE was significant at 0.003. The largest impact on the proposed FE factor was from the PD construct with a regression weight of 0.527.

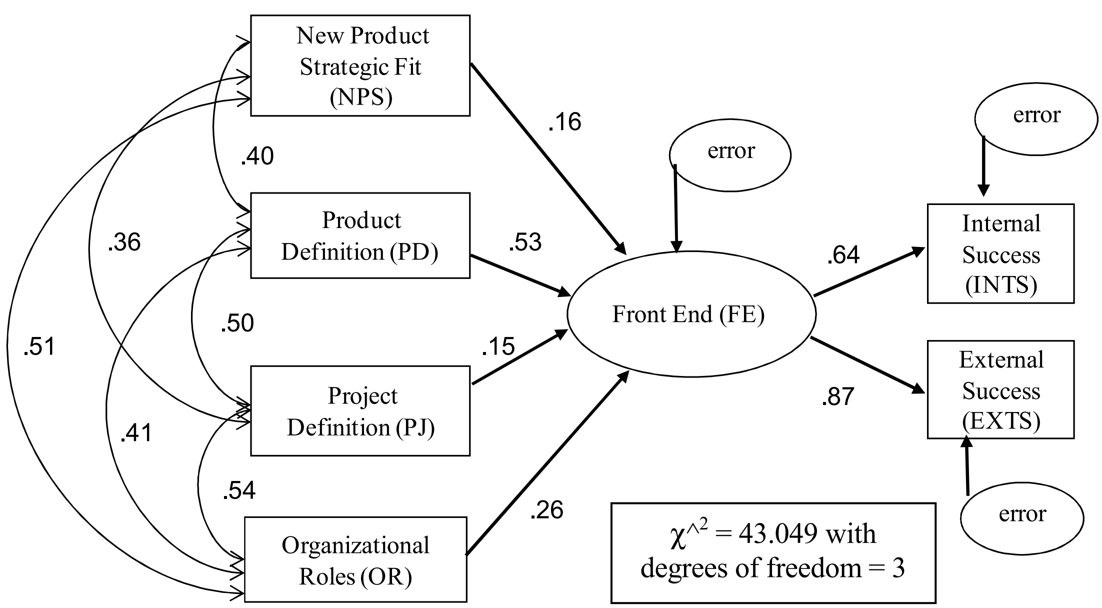


Figure 5.2. Structural Model with Standardized Regression Weights

Table 5.11 Regression Weights

			Estimate	Std. Error	p	Std. Beta
Front End	<---	New Product Strategic Fit	0.358	0.174	**0.040**	0.159
Front End	<---	Project Definition	0.369	0.201	0.066	0.153
Front End	<---	Organizational Roles	0.595	0.200	**0.003**	0.257
Front End	<---	Product Definition	1.000			0.527
Internal Success	<---	Front End	0.221	0.037	**<0.001**	0.640
External Success	<---	Front End	0.420	0.057	**<0.001**	0.868

A summary of the goodness of fit (GoF) statistics for the model is given in Table 5.12 and is organized by category of fit measurement type after Blunch (2008, p. 113). As noted in the methodology chapter, SEM GoF measures are evaluated from various categories. Each of the GoF measures were described in Table 4.1. The reporting of goodness of fit parameters for SEM varies from author to author and discipline to discipline. Within the SEM literature, there is a lack of agreement on which fit measures are best and the acceptable range of good fit. It is thus left to the researcher to decide if a model is adequate based on the underlying theory and evaluation of multiple fit indices.

Table 5.12 Goodness of Fit Indices

Measure	Goodness of Fit Measurement Category	Value
CMIN/DF	Absolute Fit Measure	14.350
RMR	Absolute Fit Measure	0.056
GFI	Absolute Fit Measure	0.924
NFI	Relative Fit Measure	0.889
CFI	Relative Fit Measure	0.893
PRATIO	Parsimony Adjusted Measures	0.200
RMSEA	Non-central Chi-square Distribution	0.297
AIC	Information Theory Measure	Default model = 79 Saturated model = 42 Independence model = 401

The fit index of CMIN/DF which is based on the χ^2 distribution is higher than the recommended value. However, as Byrne (2001, p. 81) pointed out, "findings of well-fitting hypothesized models, where the χ^2 value approximates the degrees of freedom, have proven to be unrealistic in most SEM empirical research." This measure of fit is not the most useful and has been replaced by different measures by most researchers. The RMR value will range from zero to 1.00, with well fitting models at 0.05 or less. The value of 0.056 is moderate for this research. The value of GFI will range from zero to 1.00 with values close to 1.00 indicating good fit. The value of 0.924 is adequate. The NFI (0.889) and CFI (0.893) will range from zero to 1.00 and have been deemed acceptable if over 0.90. The NFI and CFI fits measures are moderate for this model.

The PRATIO is computed relative to NFI and CFI with complexity of the model accounted for. Values for the PRATIO when greater than 0.50 have been quoted for acceptable fit. The PRATIO of 0.200 is an indication of poor fit. In the case of this model, one reason for this could be more paths present than needed for to fit the data (Table 4.1). Based on the regression weights, the project definition to the front-end path is insignificant. Removing insignificant paths did lead to increases in this fit value, but doing so changes the theory that is being tested. This is also supported by the mixed support for the hypotheses from the earlier regression analysis as the front-end construct variables impacted the internal and external success dimensions differently.

For the root mean square error of approximation (RMSEA), smaller is better, with 0.0 indicating perfect fit. Values less than 0.1 are a good fit. The value here was 0.297. The RMSEA fit measure is dependent on sample size, and small samples have been shown to impact this measure. The AIC measures are used to compare two or more models. The actual value has no meaning, but smaller is better.

Given the sample size and model complexity, the overall model fit across multiple measures was comparable to other NPD research utilizing SEM (Sahay and Riley, 2003; Sherman, Berkowitz, et al., 2005; Calantone, Chan, et al., 2006). Overall, there was mixed support for model fit to this data. The biggest impact of the moderate fit can be attributed to a fairly low sample size and the underlying distributions of the data. Structural models require a significant sample size. With a sample size of 152, modeling in SEM is difficult. Additional data would be required to increase the confidence. The underlying distributions of the factors are all based on Likert scales that have been treated as normal data. While treating Likert scaled data this way is a fairly standard practice for this type of empirical research, it is not without complications. Transformations were performed on the data, but there was negligible improvement in model fit.

Removing less significant paths from the model did improve certain fit measures. However, modification to the model changes the underlying questions for this research, which was to validate the holistic front-end model on the corresponding impact on product success. While the fit measures may be only moderate for this model, the researcher has to consider the purpose and expectations for the research. For the purposes of the presented research, the sample size, the prior regression analysis, and CFA of the measurement model were taken into account. Given the research purpose to evaluate the prior reported success factors of a holistic front-end, the fit was deemed acceptable for discussion purposes of the model and factors.

Based on the SEM analysis, for this data and sample, there is partial support that the four front-end critical success factors (NPS, PD, PJ, OR) make up a construct termed the holistic front-end. The PJ construct was not significant in the model ($p=0.066$). The NPS construct was moderately significant ($p=0.04$). The PD and OR constructs had the greater impact. There was significance of the FE on success. The FE had a higher regression weight (0.868) on external success than on internal success (0.640). This is partially due to the strong impact of the product development construct on external success, as was seen from the earlier regression analysis.

Although the sample size is considered small for the given number of variables, the SEM model was also run with the full indicator model and the raw data for comparison. A number of competing SEM models were run for comparison. Appendix N contains the models and the results.

K. Internal Success on External Success – SEM Model

A competing SEM model was run with the hypothesis that internal success is positively related to external success.

> H7: Internal operational-based success is positively related to external market-based success of the product.

Regression weights and significance are given in Table 5.13. The path from the internal success (INTS) to external success (EXTS) was significant (p=0.001). The null of H7 is thus rejected. The addition of this path shows the impact that internal success does predict an increase in external success and supports the hypothesis. The figure for this model is given in Appendix O. Model fit is unchanged by addition of this path, and therefore the results are not repeated here.

Table 5.13 Regression Weights and Significance

			Estimate	S.E.	P	Std. Beta
Front End	<---	Product Definition	1.000			0.608
Front End	<---	Organizational Roles	0.595	0.200	**0.003**	0.296
Front End	<---	Project Definition	0.369	0.201	0.066	0.177
Front End	<---	New Product Strategic Fit	0.358	0.174	**0.040**	0.183
Internal Success	<---	Front End	0.221	0.037	**<0.001**	0.554
External Success	<---	Internal Success	0.279	0.087	**0.001**	0.200
External Success	<---	Front End	0.358	0.054	**<0.001**	0.642

L. Moderating Effect of Innovation Level on Success

The moderating effect of innovation level on success was tested with a modified regression analysis to test H6a and H6b.

> H6a: The innovation level of the product will moderate the front-end variable impact on the internal success of the product.
>
> H6b: The innovation level of the product will moderate the front-end variable impact on the external success of the product.

The new to the company (NTC) project types were the higher level of innovation when compared to the addition to existing lines (AEL) and product improvements (IM). The NTC was coded as a dummy variable (value of 1) for the regression model. The AEL and IM were coded with a value of 0. These two innovation levels of AEL and IM were combined for the moderator analysis based on the ANOVA analysis for innovation level results which showed no difference on success.

The innovation level did have a significant moderating effect on the internal success variable and the null was rejected for H6a at an alpha of 0.05 (Table 5.14). The moderating effect of innovation explained 5.16% (R^2 change) of the variance in internal success above and beyond the variance explained by new product strategic fit, product definition, project definition, organizational roles, and innovation level (p=0.001). Additionally, the moderating effect of innovation explained 6.4% (R^2 change) of the variance in internal success above and beyond the variance explained by new product strategic fit, product definition, project definition, organizational roles, and innovation level when the cross-terms are included (p=0.005). This result can have managerial significance in the way projects are planned and executed.

Table 5.14 Effect of Front-end Variables on Internal (Operational-based) Success with Moderating Variable of Innovation Level

Model	R^2	R^2 Change	F Change	Partial F Value	Sig F Change
1	0.4794	0.0516	-0.555	13.182	0.001
2	0.5435	0.0641	-7.433	4.528	0.005

1: Full Model Predictors: Constant, NPS, PD, PJ, OR, INN
Reduce Model Predictors: Constant, NPS, PD, PJ, OR
2: Full Model Predictors: Constant, NPS, PD, PJ, OR, NPS*INN, PD*INN, PJ*INN, OR*INN, INN
Reduce Model Predictors: Constant, NPS, PD, PJ, OR, INN

The innovation level did not have a significant moderating effect on the external success variable and the null failed to b rejected for H6b at alpha of 0.05 (Table 5.15). It is also important to point out that the method does not include a comparison between the baseline expectations of one project to another, i.e., do projects that are NTC expect higher returns or market share than those that do not. The items for this research were worded such that the response captured meeting the expected success. So, it could still be true that more innovative products had different expectations to begin with for market-based success. The impact of innovation level to relative market success between projects could be explored in future research. The moderated multiple regression analysis details and partial F calculations are given in Appendix P.

Table 5.15 Effect of Front-end Variables on External (Market-based) Success with Moderating Variable of Innovation Level

Model	R^2	R^2 Change	F Change	Partial F Value	Sig F Change
1	0.5831	0.0008	-9.413	0.2533	$p >> 0.1$
2	0.6097	0.0266	-14.719	2.249	$0.05 < p < 0.1$

1: Same as shown for Table 5.14.
2: Same as above for Table 5.14.

M. Impact of Internal Success on External Success

A regression model tested the hypothesized correlation of the items of the internal success scale on the external success factor (H7).

H7: Internal success is positively related to external success of the product.

As described earlier, the internal success variable is comprised of time to market, project schedule, project budget, and project scope. There was mixed support for this hypothesis. Time to market, project schedule, and project scope were significant in the model (Table 5.16).

Table 5.16 Effect of Internal Success Items on Market-based Success Factor

	Parameters	p value
Intercept	0.471	<.0001
Time to Market*	**0.345**	**<.0001**
Project Schedule*	**-0.226**	**0.0005**
Project Budget	-0.021	0.7351
Project Scope*	**0.368**	**<.0001**
R^2	0.535	
Adjusted R^2	0.522	
F-value	41.713	
N	150	

The time to market and project scope variables were the most significant variables in the model. Project schedule had a significant negative relationship on external success. As the project schedule increases and runs over, there would be an expected negative impact on market-success due to lateness of introduction of the product to the market. The budget item was not significant to external success, as a customer or the market would have little sympathy for the project budget as these are not fee-based or contract-based products. Additionally, the company spending some percentage more on the project budget to meet schedule typically pales in comparison to the expected and anticipated return of the new product. In a business driven by consumer demand and market timing, schedule is more important than budget. Missing the release can mean the loss of a design-in for a laptop or mobile phone introduction. The fit analysis, residual plot, and ANOVA tables are given in Appendix Q.

N. Summary

The analysis of this data provided general support for the holistic front-end factor on product success. The survey was validated using confirmatory factor analysis methods. There were two questions of the twenty eight total questions that had questionable loading. The data was analyzed for various control and demographic variables. Individually, the variables of new product strategic fit, product definition, project definition, and organizational roles impacted success on different dimensions. New product strategic fit and project definition had a stronger impact on the internal measures of success. The results showed that ensuring the NPD project is aligned and planned properly can positively improve time, cost, and scope metrics for a project.

The product definition and organizational roles had a positive impact on the external success of the product. By considering the customer and market needs along with the proper organizational roles to guide the project during the front-end, an increase in market success may be realized.

Structural equation modeling provided a way to measure the latent variable of the front-end. There was moderate support for the model by showing the positive and significant relationships along the paths. However, based on the data analyzed it was evident that the product definition construct had the strongest contribution to the front-end factor.

Additional regression models provided evidence that innovation level does moderate the internal success variable, but not the external success variable. Higher innovation products are typically more uncertain and more difficult which can lead to more unpredictable schedule, budget, and introduction timing. Finally, the positive impact of internal success on external success was validated with a regression model as well as within the structural modeling framework.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The purpose of this study was to validate the prior reported critical success factors of the front-end of new-product development on the perceived success of high-technology industry products. The conclusions from the study are presented and discussed in this section.

It is acknowledged that the sample of respondents, albeit from multiple autonomous business groups located in multiple countries, reduces the application of the results to the more general population. While the results can provide valuable information when structuring the front-end of product development, the conclusions described in this section must be interpreted in that they apply only to the target firm.

A.1. Front-end Success Factors and Dimensions of Success

The Khurana and Rosenthal (1997; 1998) holistic model of the front-end of NPD was supported with additional input from a literature review. The model was extended to include the impact of the front-end critical success factors on the success of new products in the semiconductor industry. Data to test the model was obtained using a survey methodology. The model was tested with confirmatory factor analysis and multivariate statistical techniques.

The analysis showed that for the sample in this research, the survey items measuring the front-end did load as theorized on the critical success factors of new product strategic fit, product definition, project definition, and organizational roles with the exception of two items. On the product definition (PD) scale, item PD-1 measuring if the product definition was well developed did not load with the other items of this scale. This was attributed to item wording. The project definition (PJ) construct had one item (PJ-2) measuring market contingencies that did not load with the other items on this scale. In the original source for this item, it was coupled with item PJ-1 for technical contingency planning as a single item. By breaking this item into two separate items, it was concluded that market contingency planning was associated as strongly as the other items on the project definition factor. The instrument met reliability requirements.

The multidimensional success scale was validated which supported the loading on operational and market-based success constructs. The market-based measures of success were benefits to the customer, satisfying the customer, met competitive advantage, met technical performance, met the financial objectives, and met preparation for future products. The operational measures of success were met the time to market objectives, met the project schedule, met the project budget, and met the project scope. Having the knowledge that success is multidimensional, trade-offs can be made when making project decisions. Adjusting the intended success measures for a specific project can lead to increased focus for the team. For example, knowing a priori that for a certain product it is more important to meet time to market objectives versus project budget (or vice versa) gives the team additional flexibility to plan for success.

A.2. Impact of the Front-end Construct on Product Success

In terms of which front-end factors were related to new product success, there was mixed support for the hypotheses. For the model of the front-end factors on market-based success, the factors of product definition and organizational roles were significant with a Pearson's correlation of 0.763 (R^2=0.582). The factors of new product strategic fit and project definition were not significant on market-based success in this model. The factors significant on internal success were new product strategic fit and project definition with a Pearson's correlation of 0.654 (R^2=0.428). The significance of these results is that the factors of the proposed holistic front-end model impact different dimensions of new product success.

A structural equation model of the relationships of the individual front-end factors showed significance on the front-end latent variable for three of the four factors with moderate fit. Only the project definition construct was not statistically significant (p=0.066). The front-end factor was significant to both the operational and market-based success constructs ($p<0.0001$). The data for the model also showed a positive relationship of operational success impacting the market-based success (p=0.001).

A.3. Innovation Level as a Moderating Variable

Innovation level was tested as a moderating variable on success. It was shown that the innovation level did have a statistically significant impact on the internal success. The impact on operational success may indicate that more innovative projects do impact the ability to successfully manage time, cost, and scope. It is noted that the success measurement items measured success to expectations and no adjustment for relative success to different levels of innovation was captured. There was the possibility that more innovative projects could have had a higher (or lower) expected success, on one or more dimensions of success, over less innovative projects.

A.4. Operational Success Predicted Market Success

There was mixed support for the variables in the model for operational success measures impacting market-based success. The time to market and the project scope items were significant and positively related to market-based success. Project schedule was significant and negatively related to market-based success. Project budget was not significant in the model. For the products in this sample, to achieve market success, meeting the time to market while hitting the scope were key aspects important to customers. Along the same reasoning, when the project overruns the planned schedule, there is a detrimental effect on market success should the product miss the customers expected delivery. The fact that project budget was not significantly related to external success was not unexpected as the internal spending on projects does not typically impact market-based success measures. There are the certain instances where capital intensive projects may have a significant dollar value budget relative to financial return, but these projects more often than not, are portfolio based and impact a family of products and not individual products.

B. Limitations of the Research

As with all research, there are limitations which must be considered when applying the results. The following are considerations for the reader related to the results presented in this dissertation.

(1) Acknowledgement of a single high technology organization. One limitation of this research is that the main data sample was from a single organization in a single industry. As to the cross-industry generalizations, the stated purpose of this research was to examine the impact of the prior reported front-end critical success factors on the perceived success of high technology new products. While the organization studied for the main sample was from a single global company, the business units were assembled largely through acquisition and operate fairly autonomously in the high technology semiconductor industry.

The decision to focus on a particular industry was made because much of the past research was across many industries. The importance of studying homogenous samples for the NPD construct was discussed in the literature review. The homogeneity of the sample can also reduce noise and extraneous variation and allow isolation on the effect of interest (Highhouse and Gillespie, 2009). With respect to multi-company sampling, Highhouse and Gillespie (2009, p.253) summarized the work of Campbell stating, "the similarities between convenience and field samples are greater than the differences, and any differences are usually unrelated to the research questions." This is especially true when studying NPD processes based on the inputs of those who are involved in the day-to-day development activity. On the adequacy of using such a sample to test the theory, the respondents were involved in NPD projects. Highhouse and Gillespie (2009) also reported that if respondents are among the people covered by the theory, then this is an appropriate sample on which to test the theory.

Whether the results found in one industry, or one organization, can be generalized to all industries of course can be questioned. On the other hand, other authors cite that strategic success was industry specific, so the reliability of pooling industries is questionable (Balachandra and Friar, 1997). Certainly, the results cannot be overly generalized, but the addition to the body of knowledge can certainly be applied by this company, the industry, and possibly even other industries for continuous learning. Even within the studied industry, there are still certain risks in applying the results to the more general population of the semiconductor industry, and no claims are made about such extensions.

(2) There was no longitudinal measurement across these products. There could be advantages to following products from the early front-end phase through the end of the defined new product life-cycle of three years. The scope for this doctoral research was considered for time, cost, and most importantly to study the front-end critical success factors and not the entire development process. The research was designed to validate the prior reported critical success factors of the front-end. No assumptions can be made that the activity was more or less formal during the follow-on NPD segments. As pointed out in the literature section, success could be dependent on the interaction of the entire NPD process.

(3) The data analysis used Likert-based scales as continuous data. While the treatment of survey data in this way is typical for this type of research and transformations were tested, there are still statistical assumptions that were made in using these scales that are acknowledged.

(4) There were environmental factors beyond the control of this research. During the course of this study, most of the world was in a recession. This could have impacted the adoption of new technology for which these products are so dependent. There is no measurement or adjustment made for such possible extraneous impacts. As an example, one could imagine, had the study been conducted during the dot-com boom between the years of 1995 to 2000, a higher level of product success for electronics may have been reported – but one will never actually be sure.

C. Recommendations

(1) Measure success on multiple dimensions. As the data has shown, success is multidimensional and certain front-end success factors played a stronger role than other factors on the various dimensions of success. A focus on the product definition and organizational roles constructs may possibly lead to more successful products when it comes to market-based measures. However, a focus on project definition and new product strategic fit are both critical for meeting the expectations of time, cost, and scope for operational success measures. The relationship that operational success positively impacts market-based success shows both must be acknowledged and planned accordingly.

The particular organization of this research can structure their process to measure success on a multidimensional scale for the products. The multidimensional scale can then be tested with respect to the level of front-end success factor usage on particular projects.

Through continuous monitoring of the important factors, the learning can be applied to improve the overall success rate.

(2) **Adjust the front-end based on innovation level**. The data showed that innovation level can impact the operational success of a product. Organizing the front-end process to plan activity for the new product strategic fit and project definition success factors, based on innovation level, can improve success. New product projects should be classified by innovation level during the NPS portfolio process. Technical and marketing contingency planning processes can be tailored based on the type of product innovation level. Skills and resource planning can likewise be adjusted to ensure that the right skills are allocated based on the type of product innovation. Thus adjusting the NPD process according to the innovation level can be an important objective towards continuous improvement efforts to raise product success rates. One standard front-end process, applied in the same fashion, for all types of new product projects may not be appropriate.

(3) **Define the Front-end Process**. The organization should create a clearly defined process for the front-end, using this critical success factor understanding. By doing so, it would be expected that the Fuzzy Front-end segment of new product development can become less "fuzzy." While it may certainly be true that the product ideas, concepts, and the market will be fuzzy during this time, this does not mean the processes and activities of this stage need to be remain fuzzy as well. High technology organizations should make the effort to define their front-end process in terms of the critical success factors of new product strategic fit, product definition, project definition, and organizational roles. The process activity should be defined according to various innovation levels of the particular new products.

The process should also acknowledge the multidimensional aspect of success. It is likely that not all projects should be measured on the same dimensions. The project champions and sponsors should utilize the proper success measurement based on the type of project and which dimensions of both internal and external success are most important in specific situations. Acknowledging this fact can provide clarity and guidance to the resources who are working on the project to ensure they are adding the most value towards the expectations of a successful outcome.

D. Areas of Future Research

There are a number of possible areas for future research in the area of NPD front-end success factors.

(1) Perform a longitudinal study over a product's life. A longitudinal study that follows projects from beginning to the end of a defined new product life, to assess how the process and activities vary across the NPD cycle, would add to the understanding of success factor to success correlation. This could be accomplished through the addition and validation of execution, launch, and first years of production segment critical success factors to the survey instrument.

(2) Compare data across firms and across industries. A comparison of firms in the same or similar high technology industry would be recommended to test the theory for more general application. Likewise, a sample comparison across industries of dissimilar attributes could be interesting to examine the generalization concepts more fully.

(3) Compare the expected to actual results adjusted for innovation level. A possibility for future research would be to capture expected results to actual results. This would help to further understand the success with respect to innovation level as a moderator variable. The hypothesis that innovation level moderated success was not adjusted for the possibility that more innovative products may have had higher or lower expectations from a market success perspective. This could most easily be done for the financial measure. Other measures for market-based success may require different item creation with direct feedback from customers.

(4) Explore the formality of organizational roles during the front-end. Given the finding that organizational roles was the only front-end factor that was statistically significant across the innovation levels, additional research in that area could be useful. Formality of organizational roles during the front-end can be tested for impact on success dimensions.

(5) Test the front-end model on new to the world product innovations. New to the world product innovations were specifically not included in this research. An area for future research could be the testing of the critical success factors noted in this research on NTW products. A comparison of the factors reported here, could also be tested with those reported in the literature for NTW products.

While this work contributes to the body of knowledge for new product development, the NPD processes must continue to evolve. Firms will need to continuously improve the methodologies that they employ in the spirit of better practice or risk being left behind by their competitors.

APPENDICES

Appendix A

Institutional Review Board Application and Approvals

Pretest Instrument Approval

UAH
The University of Alabama in Huntsville

Department of Philosophy
College of Liberal Arts

Huntsville, Alabama 35899
Phone: (256) 824-6555

October 14, 2008
Tom Carbone
2 Brookview Ct.
Scarborough, ME 04074

Dear Mr. Carbone,

As chair of the IRB Human Subjects Committee, I have reviewed your proposal, *The impact of information processing during the front-end of new product development in high technology industries on perceived product success*, and have found it meets the necessary criteria for **expedited review** according to 45 CFR 46. I have approved this proposal, and you may commence your research. Please note that this approval is good for one year from the date on this letter. If data collection continues past this period, a renewal application must be filed with the IRB.

Contact me if you have any questions.

Sincerely,

Dr. William Wilkerson,
Chair, UHSC

Main Study Instrument Approval

UAHuntsville
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Nicholaos Jones
332B Morton Hall
Phone: 256.824 2338
Fax: 256.824 2387
Email: irb@uah.edu

Tom Carbone
c/o Donald Tippett, Ph.D.
Department of ISEEM
Technology Hall N135
University of Alabama in Huntsville
Huntsville, AL 35899

July 2, 2010

Dear Mr. Carbone,

As chair of the IRB Human Subjects Committee, I have reviewed your request to renew and modify your proposal, *The impact of critical success factors in the front-end of new product development on the perceived success of new products* (initially approved October 2008), and have found it continues to meet the necessary criteria for expedited review according to 45 CFR 46. I have approved this proposal. If data collection continues one year past the date of this letter, another renewal application must be filed with the IRB.

Please contact me if you have any questions.

Sincerely,

Dr. Nicholaos Jones
Chair, UHSC

OFFICE OF THE VICE PRESIDENT FOR RESEARCH
Von Braun Research Hall M-17 Huntsville, AL 35899 T 256.824.6100 F 256.824.6783

Appendix B

Subject Matter Expert Email or Letter

Subject Matter Expert Survey Review Request Template
Date:
Reviewer:

Dear (NAME):

Thank you for agreeing to provide your input to help validate the survey instrument for my Ph.D. dissertation at the University of Alabama in Huntsville. In confidence, at the enclosed weblink you will find the required materials. It is expected to take from 10 to 15 minutes. As we discussed, I would like to gather your input not on the survey for you're your responses to a product or project, but as a validity check against the defined constructs. Your important help precedes sending this revision of the survey to the next pretest study group.

The weblink contains additional information to a paper on the research. You may find that information useful to scan over. Please note that this validation survey review **does not** ask you to evaluate all the questions for his survey or the demographic items. This is done to maximize reviewers and in consideration of your time.

Most importantly, thank you for your time and responses to improve this research! If you have any questions, comments, inputs on this process or the study, please do not hesitate to contact me.

Survey Link:

Sincerely,
Tom Carbone,
Ph.D. Student
University of Alabama in Huntsville
Dissertation Committee Chair: Dr. Donald Tippett

Survey Grammar and Content Validity Reviews

Reviewer	Cycle	Experience Level	Purpose
1-A	1st	Educator and author of academic papers	Survey grammar and format review
1-B	1st	Educator and author of scientific research papers	Survey grammar and format review
1-C	1st	Ph.D. Professor and author of management and technology papers.	Survey grammar and format review
2-D	2nd	Ph.D. Engineering Management Professor of psychometric methods.	Survey development and grammar review
2-E	2nd	Ph.D. Professor and author in the area of NPD	Survey content validity review
2-F	2nd	Medical Devices, NPD Project Manager	Survey content validity review
2-G	2nd	Ph.D. consultant and author in the area of NPD.	Survey content validity review
2-H	2nd	Ph.D. candidate studying NPD and NPD practitioner	Survey content validity review
2-I	2nd	Ph.D. Professor and author in the area of NPD.	Survey content validity review
2-J	2nd	Ph.D. Professor and author.	Survey content validity review
2-K	2nd	Ph.D. Professor and author in the area of NPD. Prior survey development in the area of NPD.	Survey content validity review
2-L	2nd	Ph.D. Professor and author in the area of NPD. Prior survey development in the area of NPD.	Survey content validity review
3-M	3rd	Ph.D. Professor and author in the area of NPD. Former program manager for PDMA best practices survey.	Survey content validity review
3-N	3rd	Ph.D. Engineering Management	Survey development and grammar review
3-O	3rd	Ph.D. Professor and author	Survey review
3-P	3rd	Ph.D., lecturer, consultant, and member of the editorial board for Journal of Structural Equation Modeling	Survey review
3-Q	3rd	NPD Manager, Medical Devices	Survey review
3-R	3rd	Semiconductor Devices, NPD Program Manager	Survey review
3-S	3rd	Semiconductor Devices, NPD Design Manager	Survey review

Appendix C

Pretest Survey and Introduction Email

1. Is your organization, business unit, or group involved in new products?
Examples of a New Product can be: a service offered, an internal product or process, an end consumer product, or a business-to-business product.
Answer Choices: Yes No Do Not Know

2. Does your organization use a phase-gate like project review system for new product development? Note: Phases or Stages of New Product Development may be rigid or loosely applied in your organization. May also be called milestone reviews.

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

3. The questions to follow are related to a new product you are working on now or have worked on in the past. The product may be one that was a success, or one that was not successful. The product may have already been released to the market OR the project may be in progress now. Please enter a name (or code) that will remind you of the product development project for which you are answering.
Open ended answer

4. Which of the following most accurately describes your involvement on this project?
Choices: **Project Sponsor, Project or Program Manager, Project Team Member, Functional Manager, Other, please specify ______**

5. In a few words, please tell us a little about this product. Ex., is it an internal product, a business to business product, an end-consumer product. It is a consumer good, an IT product, a medical device, an electronic product, a service, etc.
Open ended answer

6. What is the approximate status of this project?
Complete means product has been released to the customer. Customer can be internal or external to your organization.

Do not Know	0-25% complete	26%-50% complete	51%-75% complete	76%-99% complete	Complete	Cancelled before completed

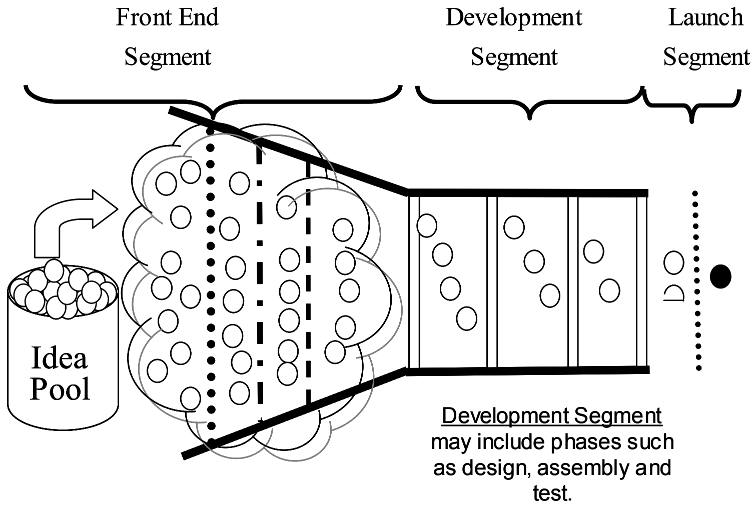
7. Where is this product within the general segments of the product development cycle?
Click for Definition Reference

Front-end	Development	Market Launch	On the Market Already

The definition by the link was provided as:

Definition of the Fuzzy Front-end

- **The Fuzzy Front-end (FFE)** is defined as the messy "getting started" period of product development, when the product concept is still very fuzzy. Preceding the more formal product development process, the front-end generally consists of three tasks: strategic planning, concept generation, and, especially, pre-technical evaluation. These activities are often chaotic, unpredictable, and unstructured.
- In comparison, the subsequent new product development (NPD) process is typically structured, predictable, and formal, with prescribed sets of activities, questions to be answered, and decisions to be made
- Reference: Belliveau, Paul, Abbie Griffin, et al. (2002). *The PDMA Toolbook for New Product Development*. New York, John Wiley & Sons, Inc.



Survey Items

8. This product development project was (or is expected) to be:

Do not know	Highly Unsuccessful	Unsuccessful	Somewhat Unsuccessful	Somewhat Successful	Successful	Highly Successful

9. Please answer the following questions in relation to the product development project you entered.

This product is "New-to-the-World."

This product is "New-to-the-Company."

This product is a "Product Improvement."

This product is an "Addition to an Existing Product Line."

This product is a "Cost Reduction."

This product is a "Repositioning."

Survey Items - Success Scale (Success)

10. Please answer the following questions in relation to the product development project you entered. This product:

(Please note the rating scale. The first box is "Do not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- Offers a number of benefits to the customer.
- Satisfied (or is expected to satisfy) the Customer.
- Met (or is expected to meet) the intended Competitive Advantage.
- Met (or is expected to meet) the intended Technical Performance.
- Met (or is expected to meet) the Financial objectives.
- Met (or is expected to meet) the Time to Market objectives.
- Met (or is expected to meet) the expected preparation for future products and strategy enhancement.
- Met (or is expected to meet) the project schedule.
- Met (or is expected to meet) the project budget.
- Met (or is expected to meet) the project scope.

Survey Items - New Product Strategic Fit (NPS)

11. For this product: (Please note the rating scale. The first box is "Do not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- There is alignment between this product and the organizational strategy.
- The product is considered as part of the product portfolio plan.
- Balancing risks is part of our product strategy.
- The project is ranked within the portfolio of projects.

Survey Items - Product Definition (PD)

12. For this product during the early front-end phase:
(Please note the rating scale. The first box is "Do Not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- Product definition is well developed.
- Product definition includes a market assessment.
- Product definition includes a technology assessment.
- Product definition includes a customer needs analysis.
- There are **no** clear priorities for product features.

Survey Items - Project Definition (PJ)

13. For this product during the early front-end phase:
(Please note the rating scale. The first box is "Do Not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- Technical contingencies are planned.
- Market contingencies are planned.
- Our engineering skill is at the required level.
- Our manufacturing / production skill is at the required level.
- Resource allocation planning is considered.

Survey Items - Organizational Roles (OR)

14. For this product during the early front-end phase of the project:
(Please note the rating scale. The first box is "Do Not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- There is a clear project manager role.
- The project team is defined.
- The project has executive sponsorship.
- Organizational communication is delivered.

Survey Items - Information Processing (IP)

15. * Each individual item is scored on the shown scale.

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

- In order to implement new product ideas, our organization adds additional development capacity, in the form of more resources to increase new product development output.
- There are typically more active projects than the resources within the organization can work on at any one time.
- We quote customers longer project timelines to product delivery than we expect.
- All resources needed for new product development are dedicated to our division.
- The product information needed is BOTH generated and used by employees within the control of our division.
- Our product development resources perform multiple functions.

16.

- Project related information is accessible to all team members, at all times.
- Project related information is updated in real time by team members as new information becomes available.
- Project related information is used by the group to make decisions.
- Informal direct contact between group members is frequently used to solve problems.
- We have specific roles defined to coordinate project information between the groups to solve problems.
- There are apparent dual authority relationships (i.e., matrix management).

Survey Items

17. Your organization considers a product, as a NEW product, typically for the following # of years:

- Less than one Year
- One
- Two
- Three
- Four
- Five
- More than Five
- Do not track
- Do Not Know

18. Your organization targets the following range of total revenue to come from new products each year:

Do Not Know	0-10%	11 – 30%	31 – 50%	51 – 75%	over 75%

19. Approximately what percentage of new products your organization introduced in the last three years would be considered a success by your organization?

Do Not Know	0-10%	11 – 30%	31 – 50%	51 – 70%	71% - 90%	Over 91%

20. How many years have you been involved in product development?

None	5 or less	6 – 10	11 – 15	16 – 20	21 – 25	over 25

21. What is the approximate number of employees within your entire company?

Under 500 500 – 2500 2500 – 10,000 10,000-25,000 25,000-50,000 over 50,000

22. What is the approximate number of employees within your business unit?

Under 500 500 – 2500 2500 – 10,000 10,000-25,000 25,000-50,000 over 50,000

Survey Items

23. What are the approximate total annual sales for your entire company?

< $25 million (M)
$25M to $100M
$100M to $250M
$250M to $500M
$500M to $750M
$750 to $1 Billion
$1 Billion to $5B
$5B Billion to $10B
Over $10B
Private Company – Not Disclosed
Do not know

24. What is the average length of the product life cycle (in years) in your industry from the time released to market to the time of product obsolescence?

0 – 3 4 – 6 7 – 9 10 – 15 16 – 25 over 25 Do not Know

25. How long does it typically take (in years) on average, to develop a new product in your organization?

(0.1 – 0.5) (0.5 – 1) (1 – 2) (2 – 4) (4 – 5) (5 – 7) (7 – 10) (Over 10) (Varies Greatly)

26. What is your job function:

- Business Development
- Marketing Engineer
- Marketing Manager / Director / VP
- Product Development Engineer
- Product Development Manager / Director / VP
- Project or Program Manager
- Operations or Manufacturing Engineer
- Operations or Manufacturing Manager / Director / VP
- New Product Process Manager
- R&D Manager
- R&D Engineer
- Other, specify

Survey Items

27. Please select the industry category that best describes your business:		
Advertising; Aerospace Agriculture Agricultural equipment Automobiles & Components Banking Computers Construction Consulting Consumer Durables & Apparel Consumer Electronics Consumer Packaged Goods Defense Related Education Electronic Components, including Semiconductors & Related Devices Energy	Financial Food, including Beverage & Tobacco Health Care Equipment & Services Hotels, Restaurants & Leisure Household & Personal Products Industrial Services & Supplies Information technology Insurance Materials, specifically Chemicals Materials, specifically Construction & Materials Materials, specifically Containers & Packaging Materials, specifically Metals & Mining	Materials, specifically Paper & Forest Products Media Publishing & Broadcasting Medical Devices Not-for-Profit Pharmaceuticals & Biotechnology Real Estate Retailing (Other than Food & Drug) Software & Services Technology Hardware & Equipment Telecommunication Services Transportation Travel Utilities Other, Please specify
28. In what country do you work? (Fill in box)		
29. OPTIONAL INFORMATION However, this is required if you would like a personalized report. Furthermore, you will be notified of free Webcasts and events scheduled to share the information. Your name and/or organization will not appear in any publications or reports according to University requirements. Your Name Your Email		
30. OPTIONAL INFORMATION: Do you know someone else who would be interested in participating in this research to learn more about product success? If so, please enter their name and email below, or forward them the link to the survey: Name Email		
31 Optional comments or questions:		

Pretest Introduction Email

The Impact of the Front-end on New Product Success

Dear New Product Development Professional:

A significant amount of research has been published in the area of New Product Development (NPD). Nevertheless, published market success rates for launched new products have remained relatively flat. This is a critical research area, as any increase in the success rate of launched new products can lead directly to an increased return on investment.

I am conducting new product research at the University of Alabama in Huntsville. The goal of this research is to better understand how organizations deal with new product information and the impact on product success.

I request your help in this study by participating in this short survey. **Your responses will remain confidential.** All participants who include their optional contact information will receive a free copy of the final report. Thank you for your support.

Tom Carbone, Ph.D. Candidate - University of Alabama in Huntsville

Committee Chair: Donald Tippett, D.Eng., Associate Professor

Appendix D

Pretest Supporting Data

Innovation Level Adjustments

Initially 41% of submitted products were classified as New to the World (NTW). Literature notes that NTW products typically account for less than 10% of new products. The high percent of NTW reported was uncharacteristic. Follow-up discussions were held with 5 of the respondents, who had supplied contact information, and had classified their project as NTW. For example, one NTW product submitted was described as, "new chemical resistant glove with enhanced wet grip, moisture management, and tactile sensitivity." It was determined after the conversation that this product was actually an improvement over existing products where a glove already existed. Based on the follow-up conversations, this type of product innovation progressions were commonplace for those products originally selected as NTW. For the remaining NTW selections the description of the product were used by the researcher and independently by one other NPD professional to sort the selected NTW projects against the innovation classification. Following the affinity grouping there were four projects which by the description may have been truly considered NTW and could not be verified with the respondent. These were described for example as "new insulation to coat customer products," and "a new weapon system." It was decided, to leave these projects in the dataset for the pretest analysis. Table 4.6 is the final innovation level distribution with 6.2% included as NTW.

Pretest Do Not Know (DnK) Analysis

Distribution of DnK by Question and Respondent

Question	# of DnK by question	DnK % for the Item (# / 65 responses)
Q10-3 Success: Competitive Advantage	2	3.1
Q10-6 Success: Time to Market	3	4.6
Q10-7 Success: Preparation for the Future	2	3.1
Q10-9 Success: Budget	1	1.5
Q11-1 NPS: Alignment	1	1.5
Q11-2 NPS: Portfolio	3	4.6
Q11-4 NPS: Ranked	4	6.2
Q12-1 PD: Market	4	6.2
Q12-2 PD: Technical	1	1.5
Q12-3 PD: Customer Needs	3	4.6
Q12-5 PD: Feature Priority	3	4.6
Q13-2 PJ: Market	6	9.2
Q14-3 OR: Sponsor	1	1.5

Respondent DNK Data

# of questions with a DnK response	# of respondents in this category	DnK by respondent % (# / 28 items)
1	7	3.6%
2	3	7.1%
3	5	10.7%
4	0	0%
5	0	0%
6	1	21.4%
7 or more	0	

Pretest New Product Strategic Fit Summary Table

	Component 1	Mean	Std. Deviation	MSA[b]	Cronbach's Alpha if Item Deleted
NPS-1: Alignment	.818	1.62	1.508	0.800	.750
NPS-2: Portfolio plan	.789	1.66	1.332	0.696	.771
NPS-3: Balancing risks	.653	1.12	1.568	0.583	.830
NPS-4: Project is ranked	.915	.90	1.651	0.639	.649

N = 58
Extraction Method: Principal Component Analysis, Varimax Rotation.
a. 1 component extracted, no rotation necessary.
b. Overall Measure of Sampling Adequacy (MSA) = 0.677
c. Bartlett's Test of Sphericity, sig 0.000
d. Cronbach's Alpha = 0.806

Pretest Product Definition Summary Table

	Component	Mean	Std. Deviation	MSA[b]	Cronbach's Alpha if Item Deleted
PD-1: Product definition	.863	1.22	1.590	0.760	.744
PD-2: Market assessment	.755	.57	2.070	0.786	.792
PD-3: Technology assessment	.835	1.55	1.489	0.779	.761
PD-4: Customer needs analysis	.856	1.28	1.765	0.794	.736
PD-5: Feature priority	.517	1.16	1.852	0.789	.851

N = 58
Extraction Method: Principal Component Analysis, Varimax Rotation.
a. 1 component extracted, no rotation necessary.
b. Overall Measure of Sampling Adequacy (MSA) = 0.780
c. Bartlett's Test of Sphericity, sig 0.000
d. Cronbach's Alpha = 0.815

Pretest Project Definition Summary Table

	Component 1	Component 2	Mean	Std. Deviation	MSA[b]	Cronbach's Alpha if Item Deleted
PJ-1: Technical contingencies	**.537**	**.541**	1.07	1.400	0.593	.492
PJ-2: Market contingencies	-.043	**.922**	-.28	1.612	**0.439**	**.678**
PJ-3: Engineering skill	**.803**	.177	1.49	1.297	0.623	.509
PJ-4: Production skill	**.595**	.377	1.18	1.227	0.631	.559
PJ-5: Resource planning	**.799**	-.246	.95	1.586	0.499	.632

N = 57
Extraction Method: Principal Component Analysis, Varimax Rotation.
a. 2 components extracted.
b. Overall Measure of Sampling Adequacy (MSA) = 0.569
c. Bartlett's Test of Sphericity, sig 0.000
d. Cronbach's Alpha = 0.631

Pretest Organizational Roles Summary Table

	Component 1	Mean	Std. Deviation	MSA[b]	Cronbach's Alpha if Item Deleted
OR-1: PM role.	.876	1.60	1.498	0.769	.797
OR-2: Project team	.865	1.75	1.282	0.787	.810
OR-3: Executive sponsor	.803	1.75	1.534	0.844	.842
OR-4: Organizational communication	.822	.95	1.601	0.822	.831

N = 63
Extraction Method: Principal Component Analysis, Varimax Rotation.
a. 1 component extracted, no rotation necessary.
b. Overall Measure of Sampling Adequacy (MSA) = 0.802
c. Bartlett's Test of Sphericity, sig 0.000
d. Cronbach's Alpha = 0.859

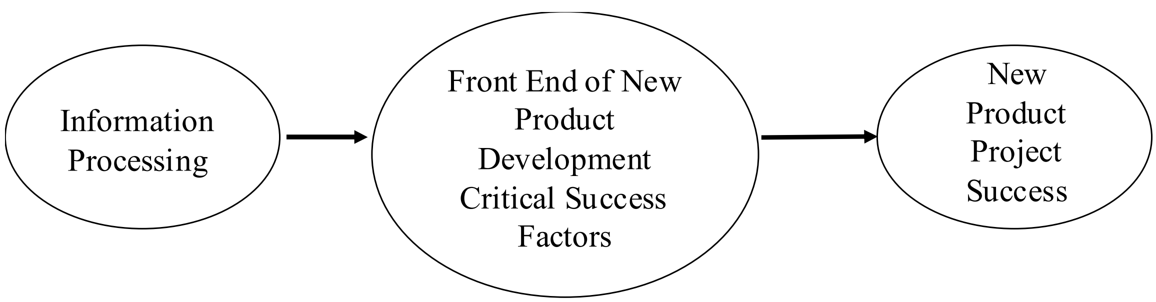
Pre-test Success Component Details

	Expected Dimension	Component 1	Component 2	Mean	Std. Deviation	MSA[b]	Cronbach's Alpha if Item Deleted
S1: Benefits to the customer	External	**.827**	.052	2.02	1.051	0.780	.918
S2: Satisfied the customer	External	**.880**	.274	1.86	1.369	.837	.907
S3: Met competitive advantage	External	**.762**	.299	1.60	1.450	.869	.911
S4: Met technical performance	External	**.632**	.501	1.71	1.228	.905	.909
S5: Met the financial objectives*	External*	.387	**.690**	.55	1.719	.783	.910
S6: Met the time to market objectives	Internal	.371	**.822**	.40	1.796	.783	.903
S7: Met preparation for future products / strategy enhancement	External	**.637**	.409	1.10	1.507	.733	.912
S8: Met the project schedule	Internal	.246	**.891**	.59	1.727	.733	.907
S9: Met the project budget	Internal	.130	**.883**	.53	1.625	.789	.912
S10: Met the project scope	Internal*	**.641***	.460	1.45	1.231	.949	.910

* Loaded opposite to expected during the pretest, see Chapter 4.
N = 58
Extraction Method: Principal Component Analysis. Varimax with Kaiser Normalization.
a. 2 components extracted
b. Overall Measure of Sampling Adequacy (MSA) = 0.826
c. Bartlett's Test of Sphericity, sig 0.000
d. Cronbach's Alpha = 0.918

Pre-test Information Processing Construct

During the early research for the dissertation an initial conceptual model included an information processing construct as shown below. The Galbraith information processing theory is often quoted in the NPD literature. Dr. Galbraith developed the theory in the 1970's. In his book, "Designing Complex Organizations," Galbraith describes the ways organizations deal with the complexity of information for the product development task on information processing (1973). Galbraith defined uncertainty as, "the difference between the amount of information required to perform the task and the amount of information already possessed by the organization," (5). Galbraith identified that it was not the uncertainty but rather, "it is information processing, and specifically information processing during actual task execution, that is the key concept," (5).



In his theory, Galbraith hypothesized what he called four exhaustive strategy alternatives to processing of information. The organization will either reduce the need for information processing or increase the capacity to process information. To reduce the information processing the organization will either create slack resources or create self-contained tasks. Slack resources add additional cost and in the realm of product development will increase the development time. The creation of self-contained tasks leads to the product organized structure which reduces the need to deal with cross-functional interfaces or priorities, but increases costs from duplication of resources. On the other hand, if the organization chooses to increase the capacity to process information they will either invest in vertical information systems or create lateral relations. The vertical information systems allow the organization to collect information needed and share it accordingly when it needs to be used. The creation of lateral resources moves decision making back down the hierarchy, typically through the use of the integrating roles such as project managers.

During the review of the pretest study results with the research committee, it was determined that validating the information processing theory of Jay Galbraith was not directly applicable to the main theme of this research to validate the holistic front-end critical success factors and the impact on product success. There were several issues with including the IPT construct within the framework for this research. There was no prior validation of the Galbraith information processing theory discovered during the literature review phase. This dissertation was interested in project level results and the Galbraith theory is at the organizational or firm level. More importantly, for this research the critical information processing aspects of new product development work were already encompassed in the survey items related to the front-end factors. It is through these front-end constructs, that the information processing was assessed as related to new product development projects. Given the items were included on the pretest instrument, analysis is provided here for the interested reader in terms of factor analysis and reliability.

The data from the pretest sample population did not reliably load on the theorized IPT factors. The factor analysis and reliability tables are shown below. There could be a number of various reasons for the poor fit. The questions could have been poorly designed. Given no prior discovery of a validation of the theory via such a factor analysis method there is no basis for comparison. One key point is the fact that knowledge work has progressed significantly since the 1970's when the theory was formulated. Teaming, communication, and dealing with project related information is certainly more part of the day to day work of knowledge workers than 40 years ago. However, without further validation the discussion of these results is left to future research.

Reduce the Need for Information Processing Survey Item Analysis

There was poor fit of the data based on the KMO and Bartlett tests.
Three components were extracted to the hypothesized one component. The negative means from these questions are statistical evidence that the sample population does not use these forms of information processing mechanisms. This would be consistent with the discussion that knowledge work today has found more proficient ways to deal with uncertainty.

Correlation Matrix[a]

		IP1	IP2	IP3	IP4	IP5	IP6
Sig. (1-tailed)	IP1		.243	.111	.335	.421	.152
	IP2	.243		.037	.027	.038	.042
	IP3	.111	.037		.073	.287	.303
	IP4	.335	.027	.073		.002	.461
	IP5	.421	.038	.287	.002		.190
	IP6	.152	.042	.303	.461	.190	

a. Determinant = .558

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.496
Bartlett's Test of Sphericity	Approx. Chi-Square	28.669
	df	15
	Sig.	.018

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.643	27.383	27.383	1.598	26.640	26.640
2	1.351	22.513	49.896	1.290	21.507	48.147
3	1.171	19.519	69.415	1.276	21.268	69.415
4	.787	13.114	82.529			
5	.566	9.440	91.969			
6	.482	8.031	100.000			

Rotated Component Matrix[a]

	Component		
	1	2	3
IP1	.062	.437	-.670
IP2	-.523	.536	.436
IP3	.153	.863	-.013
IP4	.795	.151	-.075
IP5	.810	.005	.154
IP6	.101	.209	.780

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Reliability statistics are unremarkable given the poor factor analysis validation.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.242	.263	6

Item Statistics

	Mean	Std. Deviation	N
IP1	-.17	1.541	53
IP2	-1.21	1.645	53
IP3	.81	1.415	53
IP4	.60	1.548	53
IP5	-.26	1.607	53
IP6	-1.58	1.151	53

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
IP1	-1.64	14.234	.014	.066	.283
IP2	-.60	15.167	-.086	.255	.370
IP3	-2.62	11.393	.353	.176	.001
IP4	-2.42	12.671	.155	.236	.166
IP5	-1.55	12.599	.139	.205	.178
IP6	-.23	14.409	.119	.108	.204

Increase the Capacity for Information Processing Survey Item Analysis

While this part of the IPT construct had adequate KMO and Bartlett tests, two components were extracted to the hypothesized one component. The scale means are higher for this part of the IPT theory which covers methods more apt to be used in today's knowledge worker environment.

Correlation Matrix[a]

		IP7	IP8	IP9	IP10	IP11	IP12
Sig. (1-tailed)	IP7		.000	.000	.022	.006	.044
	IP8	.000		.000	.024	.004	.001
	IP9	.000	.000		.000	.000	.013
	IP10	.022	.024	.000		.000	.293
	IP11	.006	.004	.000	.000		.087
	IP12	.044	.001	.013	.293	.087	

a. Determinant = .096

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.740
Bartlett's Test of Sphericity	Approx. Chi-Square	122.261
	df	15
	Sig.	.000

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.058	50.963	50.963	2.171	36.175	36.175
2	1.155	19.253	70.216	2.042	34.041	70.216
3	.752	12.532	82.748			
4	.443	7.387	90.134			
5	.374	6.231	96.365			
6	.218	3.635	100.000			

Rotated Component Matrix[a]

	Component	
	1	2
IP7	.325	.676
IP8	.274	.822
IP9	.675	.553
IP10	.871	.016
IP11	.877	.202
IP12	-.081	.750

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.788	.797	6

Item Statistics

	Mean	Std. Deviation	N
IP7	.61	1.580	56
IP8	.43	1.512	56
IP9	1.38	1.121	56
IP10	1.96	1.078	56
IP11	1.25	1.365	56
IP12	1.66	1.431	56

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
IP7	6.68	21.822	.544	.390	.757
IP8	6.86	21.106	.645	.515	.727
IP9	5.91	23.028	.750	.637	.715
IP10	5.32	26.149	.457	.428	.774
IP11	6.04	22.871	.583	.616	.745
IP12	5.63	25.548	.329	.188	.806

Appendix E

Figure Re-print Permissions

Reprint Permission for Figure 2.2. Product Life Cycle Cost Incurred Versus Cost Committed, from "Target Setting: Key to Successful NPD Outcomes," John J. Dutton, *PDMA Visions Magazine*, April 1998)

George Castellion <pdma_foundation@snet.net> Thu, Apr 14, 2011 at 5:07 PM
To: Tom Carbone <tom.carbone@fairchildsemi.com>
Cc: Al Page <alp3@uic.edu>

Tom,
I've just finished speaking with Professor Al Page, VP, Publications of the PDMA. He approves your request to use Figure 6 from the April 1998 article in your PhD thesis. (This figure is the same one you have a letter from Ms. Van Nostrand in 2006 granting you reprint permission for use in the PDMA FEI Conference in 2006.)

George Castellion
VP, Development, PDMA Research Foundation
(An IRS 501 (c)3 organization)
203/323-5778, pdma_foundation@snet.net
www.newproductinstitute.org

Appendix F

Main Study Introduction Email

NPD Study XYZ (Specific Name) Product

Hi ENTER-NAME-HERE

I am collecting data on past new products for a dissertation research topic.

Could you please take a few minutes to complete this survey for the (Specific Name) Product (random selection). If you were not on the team for this new product please let me know.

Your response will be kept confidential and anonymous.

Survey Link – no longer active

If you have any questions, please let me know.

Thank you
Tom Carbone
(Contact information removed)

Appendix G

Main Study Survey

New Product Study

Dear Colleague:

We are conducting a short new product study. Your response will be kept confidential and anonymous.

Thank you for your support.

Tom Carbone

Main Data Survey

1. Please enter the name of the project that you were asked to evaluate in the email:

2. Which of the following most accurately describes your involvement on this project?
Choices:

- Project Sponsor
- Project or Program Manager
- Project Team Member (please enter function below - product line, marketing, finance, etc)
- Other Stakeholder (please enter function below - product line, marketing, finance, etc)
- Other, please specify

3. What is the approximate status of this project?
Complete means product has been released to the customer. Customer can be internal or external to your organization.

Do not Know	0-25% complete	26%-50% complete	51%-75% complete	76%-99% complete	Complete	Cancelled before completed

4. Where is this product within the general segments of the product development cycle?

Definitions:

Front-end: the "getting started" period of product development which generally consists of strategic planning, concept generation, and pre-technical evaluation.

Development: the more structured set of phases for design, test, and the like.

Market Launch: when the completed product is made generally available.

Front-end	Development	Market Launch	On the Market Already

Main Data Sample Survey (continued)

5. This product development project was (or is expected) to be:

Do not know	Highly Unsuccessful	Unsuccessful	Somewhat Unsuccessful	Somewhat Successful	Successful	Highly Successful

* Each individual item is scored on the shown scale.

6. Please answer the following questions in relation to the product development project you entered.

This product is "New-to-the-World."

This product is "New-to-the-Company."

This product is a "Product Improvement."

This product is an "Addition to an Existing Product Line."

This product is a "Cost Reduction."

This product is a "Repositioning."

7. Please answer the following questions in relation to the product development specified: (Please note the rating scale. The first box is "Do not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- Offers a number of benefits to the customer.
- Satisfied (or is expected to satisfy) the Customer.
- Met (or is expected to meet) the intended Competitive Advantage.
- Met (or is expected to meet) the intended Technical Performance.
- Met (or is expected to meet) the Financial objectives.
- Met (or is expected to meet) the Time to Market objectives.
- Met (or is expected to meet) the expected preparation for future products and strategy enhancement.
- Met (or is expected to meet) the project schedule.
- Met (or is expected to meet) the project budget.
- Met (or is expected to meet) the project scope.

Main Data Sample Survey (continued)

8. For this product: (Please note the rating scale. The first box is "Do not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- There is alignment between this product and the organizational strategy.
- The product is considered as part of the product portfolio plan.
- Balancing risks is part of our product strategy.
- The project is ranked within the portfolio of projects.

9. For this product during the early front-end phase:
(Please note the rating scale. The first box is "Do Not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- Product definition is well developed.
- Product definition includes a market assessment.
- Product definition includes a technology assessment.
- Product definition includes a customer needs analysis.
- There are clear priorities for product features.

10. For this product during the early front-end phase:
(Please note the rating scale. The first box is "Do Not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- Technical contingencies are planned.
- Market contingencies are planned.
- Our engineering skill is at the required level.
- Our manufacturing / production skill is at the required level.
- Resource allocation planning is considered.

Main Data Sample Survey (continued)

14. For this product during the early front-end phase of the project:
(Please note the rating scale. The first box is "Do Not Know.")

Do Not Know	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree

* Each individual item is scored on the shown scale.

- There is a clear project manager role.
- The project team is defined.
- The project has executive sponsorship.
- Organizational communication is delivered.

12. What is your job function:
    Business Development
    Marketing Engineer
    Marketing Manager / Director / VP
    Product Development Engineer
    Product Development Manager / Director / VP
    Project or Program Manager
    Operations or Manufacturing Engineer
    Operations or Manufacturing Manager / Director / VP
    New Product Process Manager
    R&D Manager
    R&D Engineer
    Other, please specify

13. How many years have you been involved in product development?

None	5 or less	6 – 10	11 – 15	16 – 20	21 – 25	over 25

14. In what country do you work?

15. OPTIONAL INFORMATION
Your Name All responses are confidential.

16. (Optional)
Comments or questions. Open-ended

17. Please add names of others who should take this survey from the team or management who are knowledgeable about this product development project.

Appendix H

Main Data Do Not Know Analysis

Fifteen of the 152 valid respondents had selected a DnK answer on one or more of the 28 items. Question 8 from the new product strategic fit construct ("the project is ranked within the portfolio of projects") had the most DnK responses with 6 selections. The most DnK responses by project response were from a team member who chose DnK for 3 of the 28 questions.

Distribution of DnK by Question and Respondent from the Main Study

Question	# of DnK by Question	DnK % for the Item (#/152)
Q7 - S5: Financial	1	0.7%
Q7 - S9: Project Budget	1	0.7%
Q8 - NPS3: Risks	3	2.0%
Q8 - NPS4: Ranked	6	3.9%
Q9 - PD4: Customer Need	1	0.7%
Q9 - PD5: Priorities	1	0.7%
Q10 - PJ2: Market Contingency	2	1.3%
Q10 - PJ5: Resource Allocation	1	0.7%
Q11 - OR3: Sponsor	2	1.3%

DNK Total Across Respondent by Questions with DNK

# of DnK Responses Across all Questions	# of Respondents in this Category	DnK by Respondent % (# / 28 items)
1	13	3.6%
2	1	7.1%
3	1	10.7%

4 or more	0	0%

Matrix of DnK responses

Product (random coded)	Function	Q7 S5 Financial	Q7 S9 Project Budget	Q8 NPS3 Risks	Q8 NPS4 Ranked	Q9 PD4 Customer Need	Q9 PD5 Priorities	Q10 PJ2 Market Contingency	Q10 PJ5 Resource Allocation	Q11 OR3 Sponsor	# of DnK by Respondent	DnK by Respondent (#/28)
a	PM							DnK			1	3.6
b	TM				DnK						1	3.6
c	TM			DnK							1	3.6
d	TM				DnK						1	3.6
e	PM				DnK						1	3.6
f	Sponsor								DnK		1	3.6
g	Sponsor									DnK	1	3.6
h	PM			DnK							1	3.6
i	TM					DnK					1	3.6
j	Sponsor						DnK				1	3.6
k	TM				DnK						1	3.6
l	TM				DnK			DnK		DnK	3	10.7
l	TM			DnK							1	3.6
m	TM		DnK		DnK						2	7.1
n	TM	DnK									1	3.6
Item DnK #		1	1	3	6	1	1	2	1	2		
DnK % for the item (#/152)		0.7	0.7	2.0	3.9	0.7	0.7	1.3	0.7	1.3		

Appendix I

Factor Analysis and Reliability Tables

Front-end Construct Items

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.870
Bartlett's Test of Sphericity	Approx. Chi-Square	1352.930
	df	153
	Sig.	.000

Correlation Matrix[a]

		NPS1	NPS2	NPS3	NPS4	PD1	PD2	PD3
Correlation	NPS1	1.000	.743	.599	.581	.414	.388	.316
	NPS2	.743	1.000	.562	.462	.430	.299	.300
	NPS3	.599	.562	1.000	.471	.274	.170	.186
	NPS4	.581	.462	.471	1.000	.291	.392	.276
	PD1	.414	.430	.274	.291	1.000	.447	.414
	PD2	.388	.299	.170	.392	.447	1.000	.616
	PD3	.316	.300	.186	.276	.414	.616	1.000
	PD4	.313	.223	.160	.390	.445	.687	.591
	PD5	.241	.222	.224	.204	.513	.475	.432
	PJ1	.208	.236	.124	.028	.391	.247	.404
	PJ2	.270	.276	.106	.312	.414	.673	.585
	PJ3	.381	.326	.266	.227	.601	.353	.460
	PJ4	.273	.246	.268	.174	.551	.265	.293
	PJ5	.337	.279	.267	.185	.304	.280	.228
	OR1	.415	.495	.482	.292	.451	.186	.184
	OR2	.383	.355	.413	.266	.416	.272	.299
	OR3	.251	.222	.192	.281	.504	.380	.234
	OR4	.442	.490	.317	.362	.538	.374	.255
Sig. (1-tailed)	NPS1		.000	.000	.000	.000	.000	.000
	NPS2	.000		.000	.000	.000	.000	.000
	NPS3	.000	.000		.000	.001	.023	.015
	NPS4	.000	.000	.000		.000	.000	.001
	PD1	.000	.000	.001	.000		.000	.000
	PD2	.000	.000	.023	.000	.000		.000
	PD3	.000	.000	.015	.001	.000	.000	
	PD4	.000	.004	.031	.000	.000	.000	.000
	PD5	.002	.004	.004	.008	.000	.000	.000
	PJ1	.007	.003	.074	.371	.000	.002	.000
	PJ2	.001	.001	.108	.000	.000	.000	.000
	PJ3	.000	.000	.001	.004	.000	.000	.000
	PJ4	.001	.002	.001	.021	.000	.001	.000
	PJ5	.000	.000	.001	.015	.000	.000	.004
	OR1	.000	.000	.000	.000	.000	.014	.016
	OR2	.000	.000	.000	.001	.000	.001	.000
	OR3	.002	.004	.012	.000	.000	.000	.003
	OR4	.000	.000	.000	.000	.000	.000	.001

Correlation Matrix[a]

		PD4	PD5	PJ1	PJ2	PJ3	PJ4	PJ5
Correlation	NPS1	.313	.241	.208	.270	.381	.273	.337
	NPS2	.223	.222	.236	.276	.326	.246	.279
	NPS3	.160	.224	.124	.106	.266	.268	.267
	NPS4	.390	.204	.028	.312	.227	.174	.185
	PD1	.445	.513	.391	.414	.601	.551	.304
	PD2	.687	.475	.247	.673	.353	.265	.280
	PD3	.591	.432	.404	.585	.460	.293	.228
	PD4	1.000	.472	.278	.680	.364	.218	.162
	PD5	.472	1.000	.411	.442	.495	.355	.219
	PJ1	.278	.411	1.000	.474	.425	.376	.333
	PJ2	.680	.442	.474	1.000	.456	.302	.377
	PJ3	.364	.495	.425	.456	1.000	.613	.494
	PJ4	.218	.355	.376	.302	.613	1.000	.437
	PJ5	.162	.219	.333	.377	.494	.437	1.000
	OR1	.092	.209	.170	.119	.334	.300	.311
	OR2	.108	.295	.235	.206	.540	.384	.379
	OR3	.328	.339	.069	.362	.493	.332	.319
	OR4	.293	.256	.173	.384	.512	.352	.394
Sig. (1-tailed)	NPS1	.000	.002	.007	.001	.000	.001	.000
	NPS2	.004	.004	.003	.001	.000	.002	.000
	NPS3	.031	.004	**.074**	**.108**	.001	.001	.001
	NPS4	.000	.008	**.371**	.000	.004	.021	.015
	PD1	.000	.000	.000	.000	.000	.000	.000
	PD2	.000	.000	.002	.000	.000	.001	.000
	PD3	.000	.000	.000	.000	.000	.000	.004
	PD4		.000	.000	.000	.000	.005	.029
	PD5	.000		.000	.000	.000	.000	.005
	PJ1	.000	.000		.000	.000	.000	.000
	PJ2	.000	.000	.000		.000	.000	.000
	PJ3	.000	.000	.000	.000		.000	.000
	PJ4	.005	.000	.000	.000	.000		.000
	PJ5	.029	.005	.000	.000	.000	.000	
	OR1	**.141**	.007	.023	**.081**	.000	.000	.000
	OR2	.103	.000	.003	.008	.000	.000	.000
	OR3	.000	.000	**.211**	.000	.000	.000	.000
	OR4	.000	.001	.021	.000	.000	.000	.000

Correlation Matrix[a]

		OR1	OR2	OR3	OR4
Correlation	NPS1	.415	.383	.251	.442
	NPS2	.495	.355	.222	.490
	NPS3	.482	.413	.192	.317
	NPS4	.292	.266	.281	.362
	PD1	.451	.416	.504	.538
	PD2	.186	.272	.380	.374
	PD3	.184	.299	.234	.255
	PD4	.092	.108	.328	.293
	PD5	.209	.295	.339	.256
	PJ1	.170	.235	.069	.173
	PJ2	.119	.206	.362	.384
	PJ3	.334	.540	.493	.512
	PJ4	.300	.384	.332	.352
	PJ5	.311	.379	.319	.394
	OR1	1.000	.673	.339	.618
	OR2	.673	1.000	.475	.586
	OR3	.339	.475	1.000	.590
	OR4	.618	.586	.590	1.000
Sig. (1-tailed)	NPS1	.000	.000	.002	.000
	NPS2	.000	.000	.004	.000
	NPS3	.000	.000	.012	.000
	NPS4	.000	.001	.000	.000
	PD1	.000	.000	.000	.000
	PD2	.014	.001	.000	.000
	PD3	.016	.000	.003	.001
	PD4	.141	.103	.000	.000
	PD5	.007	.000	.000	.001
	PJ1	.023	.003	.211	.021
	PJ2	.081	.008	.000	.000
	PJ3	.000	.000	.000	.000
	PJ4	.000	.000	.000	.000
	PJ5	.000	.000	.000	.000
	OR1		.000	.000	.000
	OR2	.000		.000	.000
	OR3	.000	.000		.000
	OR4	.000	.000	.000	

a. Determinant = 3.06E-005 = 0.0000306 (should be greater than 0.00001)

Total Variance Explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.117	39.538	39.538	3.548	19.712	19.712
2	2.223	12.351	51.889	3.013	16.741	36.453
3	1.614	8.967	60.856	2.945	16.359	52.812
4	1.163	6.462	67.318	2.611	14.506	67.318

* First four components shown

Rotated Component Matrix[a]

	Component			
	1	2	3	4
NPS1	.232	**.827**	.153	.153
NPS2	.149	**.805**	.163	.189
NPS3	-.010	**.789**	.156	.166
NPS4	.391	**.655**	.190	-.172
PD1	**.389**	.207	***.478***	***.435***
PD2	**.821**	.177	.209	.070
PD3	**.696**	.172	.038	.322
PD4	**.874**	.123	.088	.056
PD5	**.523**	.058	.180	.430
PJ1	.274	.081	-.134	**.790**
PJ2	***.788***	.063	.128	**.296**
PJ3	.305	.112	.475	**.620**
PJ4	.125	.099	.337	**.671**
PJ5	.095	.195	.313	**.537**
OR1	-.096	.491	**.605**	.215
OR2	-.002	.310	**.683**	.329
OR3	.329	-.002	**.801**	.030
OR4	.207	.316	**.757**	.136

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Reliability Analysis
All Items Front-end Construct Reliability Statistics

Cronbach's Alpha	N of Items
.906	18

NPS Scale Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.817	.832	4

Item Statistics

	Mean	Std. Deviation	N
NPS1	1.54	1.215	143
NPS2	1.73	1.127	143
NPS3	1.15	1.267	143
NPS4	.65	1.620	143

Inter-Item Correlation Matrix

	NPS1	NPS2	NPS3	NPS4
NPS1	1.000	.741	.561	.580
NPS2	.741	1.000	.536	.464
NPS3	.561	.536	1.000	.434
NPS4	.580	.464	.434	1.000

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
NPS1	3.52	10.505	.767	.637	.715
NPS2	3.34	11.492	.688	.570	.755
NPS3	3.92	11.373	.590	.362	.792
NPS4	4.41	9.638	.572	.354	.823

Product Definition Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.836	.836	5

Item Statistics

	Mean	Std. Deviation	N
PD1	1.59	1.352	150
PD2	.91	1.634	150
PD3	1.03	1.458	150
PD4	.61	1.764	150
PD5	1.29	1.312	150

Inter-Item Correlation Matrix

	PD1	PD2	PD3	PD4	PD5
PD1	1.000	.443	.402	.426	.516
PD2	.443	1.000	.601	.682	.478
PD3	.402	.601	1.000	.597	.430
PD4	.426	.682	.597	1.000	.469
PD5	.516	.478	.430	.469	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	1.088	.613	1.593	.980	2.598	.138	5
Item Variances	2.291	1.723	3.111	1.389	1.806	.346	5

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
PD1	3.85	25.366	.544	.331	.827
PD2	4.53	21.123	.719	.547	.779
PD3	4.41	23.303	.651	.444	.799
PD4	4.83	20.278	.705	.537	.785
PD5	4.15	25.178	.584	.368	.818

Project Definition Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.774	.777	5

Item Statistics

	Mean	Std. Deviation	N
PJ1	.83	1.394	149
PJ2	.15	1.544	149
PJ3	1.50	1.383	149
PJ4	1.58	1.203	149
PJ5	.99	1.318	149

Inter-Item Correlation Matrix

	PJ1	PJ2	PJ3	PJ4	PJ5
PJ1	1.000	.471	.421	.380	.319
PJ2	.471	1.000	.414	.288	.369
PJ3	.421	.414	1.000	.598	.439
PJ4	.380	.288	.598	1.000	.403
PJ5	.319	.369	.439	.403	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	1.011	.148	1.584	1.436	10.727	.338	5
Item Variances	1.885	1.447	2.383	.936	1.647	.117	5

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
PJ1	4.23	16.691	.535	.306	.736
PJ2	4.91	15.978	.516	.304	.746
PJ3	3.55	15.830	.634	.454	.701
PJ4	3.47	17.670	.555	.396	.731
PJ5	4.06	17.436	.505	.265	.745

Organizational Roles Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.811	.826	4

Item Statistics

	Mean	Std. Deviation	N
OR1	2.03	1.141	150
OR2	1.89	.991	150
OR3	1.09	1.524	150
OR4	1.37	1.436	150

Inter-Item Correlation Matrix

	OR1	OR2	OR3	OR4
OR1	1.000	.668	.331	.617
OR2	.668	1.000	.460	.580
OR3	.331	.460	1.000	.599
OR4	.617	.580	.599	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	1.595	1.087	2.027	.940	1.865	.194	4
Item Variances	1.666	.982	2.321	1.339	2.364	.396	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
OR1	4.35	11.022	.618	.538	.770
OR2	4.49	11.473	.677	.518	.757
OR3	5.29	9.524	.548	.395	.816
OR4	5.01	8.651	.745	.563	.702

Success Construct

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.858
Bartlett's Test of Sphericity	Approx. Chi-Square	854.888
	df	45
	Sig.	.000

Correlation Matrix[a]

		S1	S2	S3	S4	S5	S6	S7
Correlation	S1	1.000	.638	.646	.384	.450	.402	.273
	S2	.638	1.000	.642	.561	.595	.541	.231
	S3	.646	.642	1.000	.480	.549	.382	.442
	S4	.384	.561	.480	1.000	.497	.498	.215
	S5	.450	.595	.549	.497	1.000	.554	.340
	S6	.402	.541	.382	.498	.554	1.000	.229
	S7	.273	.231	.442	.215	.340	.229	1.000
	S8	.203	.237	.153	.302	.415	.740	.100
	S9	.241	.337	.218	.344	.449	.664	.120
	S10	.406	.567	.483	.547	.547	.621	.327
Sig. (1-tailed)	S1		.000	.000	.000	.000	.000	.000
	S2	.000		.000	.000	.000	.000	.002
	S3	.000	.000		.000	.000	.000	.000
	S4	.000	.000	.000		.000	.000	.004
	S5	.000	.000	.000	.000		.000	.000
	S6	.000	.000	.000	.000	.000		.002
	S7	.000	.002	.000	.004	.000	.002	
	S8	.006	.002	.031	.000	.000	.000	.111
	S9	.001	.000	.004	.000	.000	.000	.072
	S10	.000	.000	.000	.000	.000	.000	.000

a. Determinant = .003

Correlation Matrix[a]

		S8	S9	S10
Correlation	S1	.203	.241	.406
	S2	.237	.337	.567
	S3	.153	.218	.483
	S4	.302	.344	.547
	S5	.415	.449	.547
	S6	.740	.664	.621
	S7	.100	.120	.327
	S8	1.000	.775	.574
	S9	.775	1.000	.638
	S10	.574	.638	1.000
Sig. (1-tailed)	S1	.006	.001	.000
	S2	.002	.000	.000
	S3	.031	.004	.000
	S4	.000	.000	.000
	S5	.000	.000	.000
	S6	.000	.000	.000
	S7	.111	.072	.000
	S8		.000	.000
	S9	.000		.000
	S10	.000	.000	

a. Determinant = .003

Total Variance Explained

Initial Eigenvalues			Rotation Sums of Squared Loadings		
Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
5.017	50.173	50.173	3.425	34.251	34.251
1.637	16.367	66.540	3.229	32.289	66.540

Rotated Component Matrix[a]

	Component	
	1	2
S1	.773	.137
S2	.790	.291
S3	.874	.097
S4	.594	.382
S5	.631	.458
S6	.363	.802
S7	.550	.027
S8	.018	.926
S9	.105	.896
S10	.494	.675

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Success Construct Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.886	.885	10

Item Statistics

	Mean	Std. Deviation	N
S1	1.13	1.464	150
S2	1.10	1.566	150
S3	.70	1.725	150
S4	1.65	1.300	150
S5	.12	1.882	150
S6	.53	1.831	150
S7	.97	1.285	150
S8	.67	1.863	150
S9	.88	1.813	150
S10	1.25	1.680	150

Inter-Item Correlation Matrix

	S1	S2	S3	S4	S5	S6	S7	S8
S1	1.000	.638	.646	.384	.450	.402	.273	.203
S2	.638	1.000	.642	.561	.595	.541	.231	.237
S3	.646	.642	1.000	.480	.549	.382	.442	.153
S4	.384	.561	.480	1.000	.497	.498	.215	.302
S5	.450	.595	.549	.497	1.000	.554	.340	.415
S6	.402	.541	.382	.498	.554	1.000	.229	.740
S7	.273	.231	.442	.215	.340	.229	1.000	.100
S8	.203	.237	.153	.302	.415	.740	.100	1.000
S9	.241	.337	.218	.344	.449	.664	.120	.775
S10	.406	.567	.483	.547	.547	.621	.327	.574

Inter-Item Correlation Matrix

	S9	S10
S1	.241	.406
S2	.337	.567
S3	.218	.483
S4	.344	.547
S5	.449	.547
S6	.664	.621
S7	.120	.327
S8	.775	.574
S9	1.000	.638
S10	.638	1.000

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	.902	.120	1.653	1.533	13.778	.181	10
Item Variances	2.739	1.650	3.543	1.892	2.147	.515	10

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
S1	7.89	115.457	.562	.508	.879
S2	7.92	110.343	.684	.664	.871
S3	8.32	110.353	.606	.603	.876
S4	7.37	116.704	.602	.432	.877
S5	8.90	104.883	.697	.511	.869
S6	8.49	103.728	.757	.709	.864
S7	8.05	123.843	.343	.260	.891
S8	8.35	109.624	.569	.738	.880
S9	8.14	108.672	.617	.665	.876
S10	7.77	106.140	.761	.628	.865

Appendix J

Control and Demographic Variables

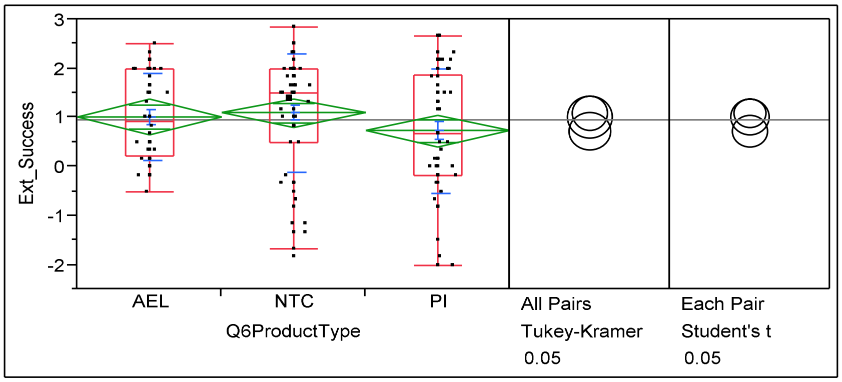
Descriptive Measures for Product Innovation Level by Front-end Factor

Front-end Factor	Descriptive	Innovation Level		
		Addition to Existing Lines (AEL)	New to the Company (NTC)	Product Improvements (PI)
New Product Strategic Fit (NPS) (p = 0.097)	Mean	1.52	1.28	1.02
	Std. Dev.	0.96	1.04	1.15
Product Definition (PD) (p = 0.17)	Mean	0.82	1.2	0.79
	Std. Dev.	1.46	1.25	1.07
Project Definition (PJ) (p = 0.462)	Mean	1.56	1.09	1.13
	Std. Dev.	0.93	0.94	1.07
Organizational Roles* (OR) (p = 0.0001)	Mean	2.19	1.53	1.18
	Std. Dev.	0.73	0.99	1.07

Descriptive Measures based on Project Role

Factor	Descriptive	Project Role		
		Project Manager (PM)	Team Member (TM)	Sponsor (Spons)
External Success (p = 0.475)	Mean	1.00	1.03	0.74
	Std. Dev.	1.15	1.10	1.26
Internal Success (p = 0.729)	Mean	0.929	0.802	0.669
	Std. Dev.	1.53	1.47	1.77
NPS (p = 0.847)	Mean	1.30	1.28	1.18
	Std. Dev.	0.99	0.99	1.28
Product Definition (p = 0.952)	Mean	0.94	0.95	1.02
	Std. Dev.	1.23	1.34	1.22
Project Definition (p = 0.442)	Mean	1.13	1.23	1.40
	Std. Dev.	1.08	0.89	0.98
Organizational Roles (p = 0.638)	Mean	1.60	1.51	1.73
	Std. Dev.	1.04	1.10	0.91

External Success by Q6 – Product Type



Missing Rows 1

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Q6ProductType	2	3.86894	1.93447	1.4555	0.2366
Error	148	196.70758	1.32911		
C. Total	150	200.57653			

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
AEL	40	1.01250	0.88706	0.14026	0.72880	1.2962
NTC	61	1.09563	1.21047	0.15498	0.78561	1.4056
PI	50	0.73000	1.26253	0.17855	0.37119	1.0888

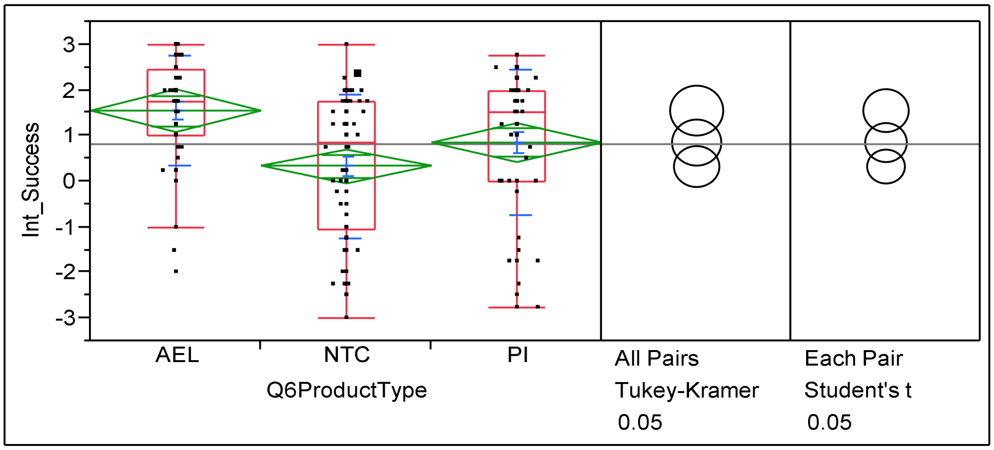
Means Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.36757	0.05

Abs(Dif)-LSD	NTC	AEL	PI
NTC	-0.49423	-0.4722	-0.15508
AEL	-0.4722	-0.61033	-0.29651
PI	-0.15508	-0.29651	-0.5459

Positive values show pairs of means that are significantly different.

Internal Success by Q6 – Product Type



Missing Rows 1

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Q6ProductType	2	35.98123	17.9906	8.1111	0.0005*
Error	148	328.26794	2.2180		
C. Total	150	364.24917			

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
AEL	40	1.55000	1.19856	0.18951	1.167	1.9333
NTC	62	0.33468	1.57461	0.19998	-0.065	0.7346
PI	49	0.85714	1.58771	0.22682	0.401	1.3132

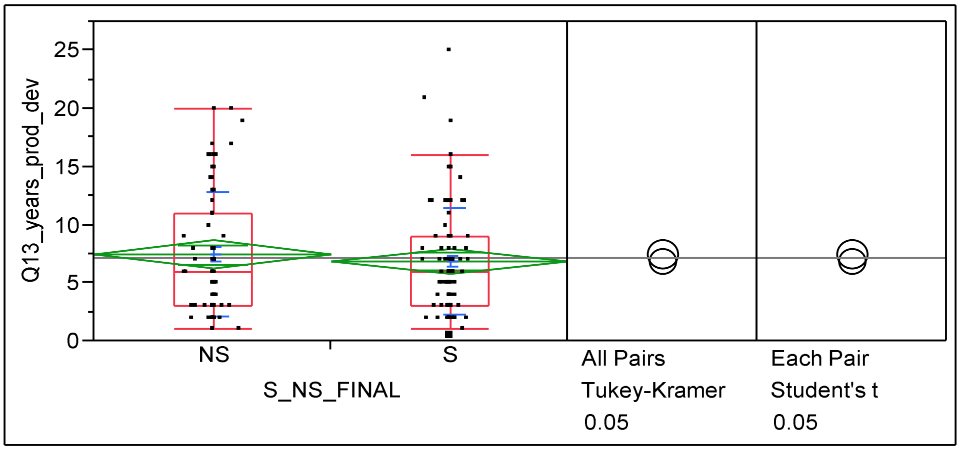
Means Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
2.36757	0.05

Abs(Dif)-LSD	AEL	PI	NTC
AEL	-0.78844	-0.05851	0.500233
PI	-0.05851	-0.71237	-0.15152
NTC	0.500233	-0.15152	-0.63329

Positive values show pairs of means that are significantly different

Q13 - Years of Product Development Experience by Success or Less Successful



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
S_NS_FINAL	1	12.6184	12.6184	0.5111	0.4758
Error	150	3703.4802	24.6899		
C. Total	151	3716.0987			

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
NS	67	7.46269	5.37764	0.65698	6.1510	8.7744
S	85	6.88235	4.62244	0.50137	5.8853	7.8794

Means Comparisons for all pairs using Tukey-Kramer HSD

q*	Alpha
1.97591	0.05

Abs(Dif)-LSD	NS	S
NS	-1.6963	-1.02365
S	-1.02365	-1.50602

Positive values show pairs of means that are significantly different.

*** Similar statistics by each construct of new product strategic fit, product definition, project definition, organizational roles, and region were analyzed and showed no significant difference and are not shown.**

Appendix K

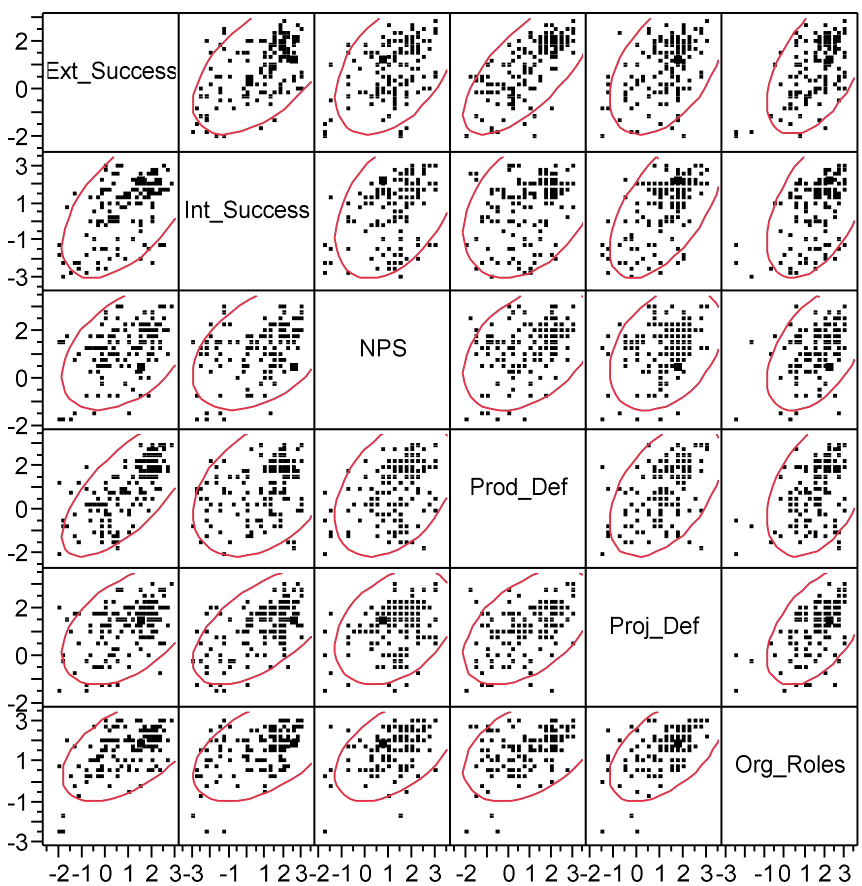
Main Sample Multivariate Data Summary

Correlation Table is found in Chapter 5.

Pairwise Correlations

Variable	by Variable	Correlation	Count	Lower 95%	Upper 95%	Signif Prob
Int_Success	Ext_Success	0.5548	150	0.4330	0.6567	<.0001*
NPS	Ext_Success	0.4644	142	0.3244	0.5844	<.0001*
NPS	Int_Success	0.4389	143	0.2960	0.5625	<.0001*
Prod_Def	Ext_Success	0.7104	149	0.6205	0.7819	<.0001*
Prod_Def	Int_Success	0.3678	149	0.2200	0.4991	<.0001*
Prod_Def	NPS	0.4031	141	0.2548	0.5329	<.0001*
Proj_Def	Ext_Success	0.4640	150	0.3282	0.5811	<.0001*
Proj_Def	Int_Success	0.5982	150	0.4844	0.6921	<.0001*
Proj_Def	NPS	0.3673	142	0.2156	0.5016	<.0001*
Proj_Def	Prod_Def	0.4945	149	0.3625	0.6070	<.0001*
Org_Roles	Ext_Success	0.5289	149	0.4023	0.6357	<.0001*
Org_Roles	Int_Success	0.4972	149	0.3657	0.6093	<.0001*
Org_Roles	NPS	0.5090	142	0.3757	0.6216	<.0001*
Org_Roles	Prod_Def	0.4107	148	0.2670	0.5365	<.0001*
Org_Roles	Proj_Def	0.5350	149	0.4094	0.6407	<.0001*

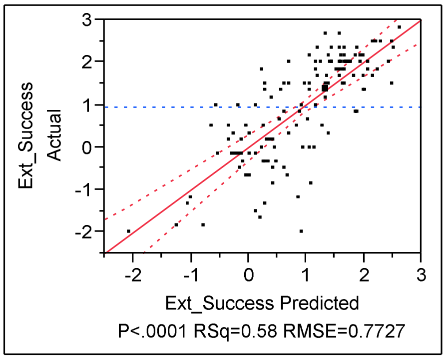
Main Sample Multavariate Scatterplot Matrix



Appendix L

Front-end Variables Regression on External Success

Response Ext_Success Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.58228
RSquare Adj	0.56972
Root Mean Square Error	0.77269
Mean of Response	0.92995
Observations (or Sum Wgts)	138

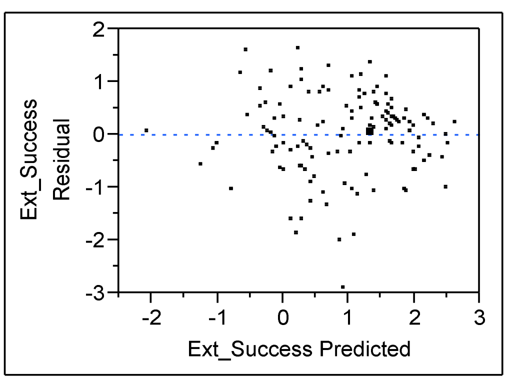
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	110.692	27.673	46.35
Error	133	79.407	0.5971	**Prob > F**
C. Total	137	190.100		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	-0.143708	0.126625	-1.13	0.2585	-0.394	0.1068	0
NPS	0.124995	0.07443	1.68	0.0954	-0.022	0.2722	0.1140
Prod_Def	0.533997	0.06279	8.50	<.0001*	0.4097	0.6582	0.5750
Proj_Def	0.001731	0.08233	0.02	0.9833	-0.1611	0.1646	0.0015
Org_Roles	0.257107	0.08194	3.14	0.0021*	0.0950	0.4192	0.2278

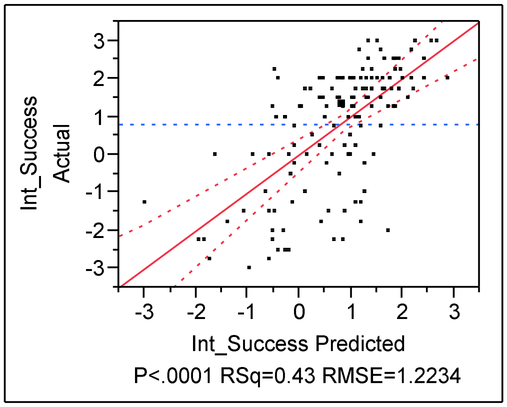
Residual by Predicted Plot



Appendix M

Front-end Variables Regression on Internal Success

Response Ext_Success Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.42784
RSquare Adj	0.41076
Root Mean Square Error	1.22341
Mean of Response	0.77518
Observations (or Sum Wgts)	139

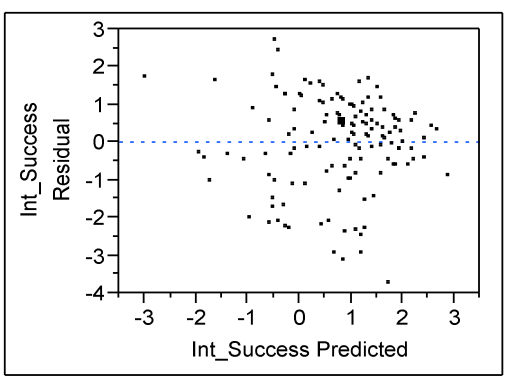
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	149.975	37.49	25.05
Error	134	200.562	1.497	**Prob > F**
C. Total	138	350.537		<.0001*

Parameter Estimates

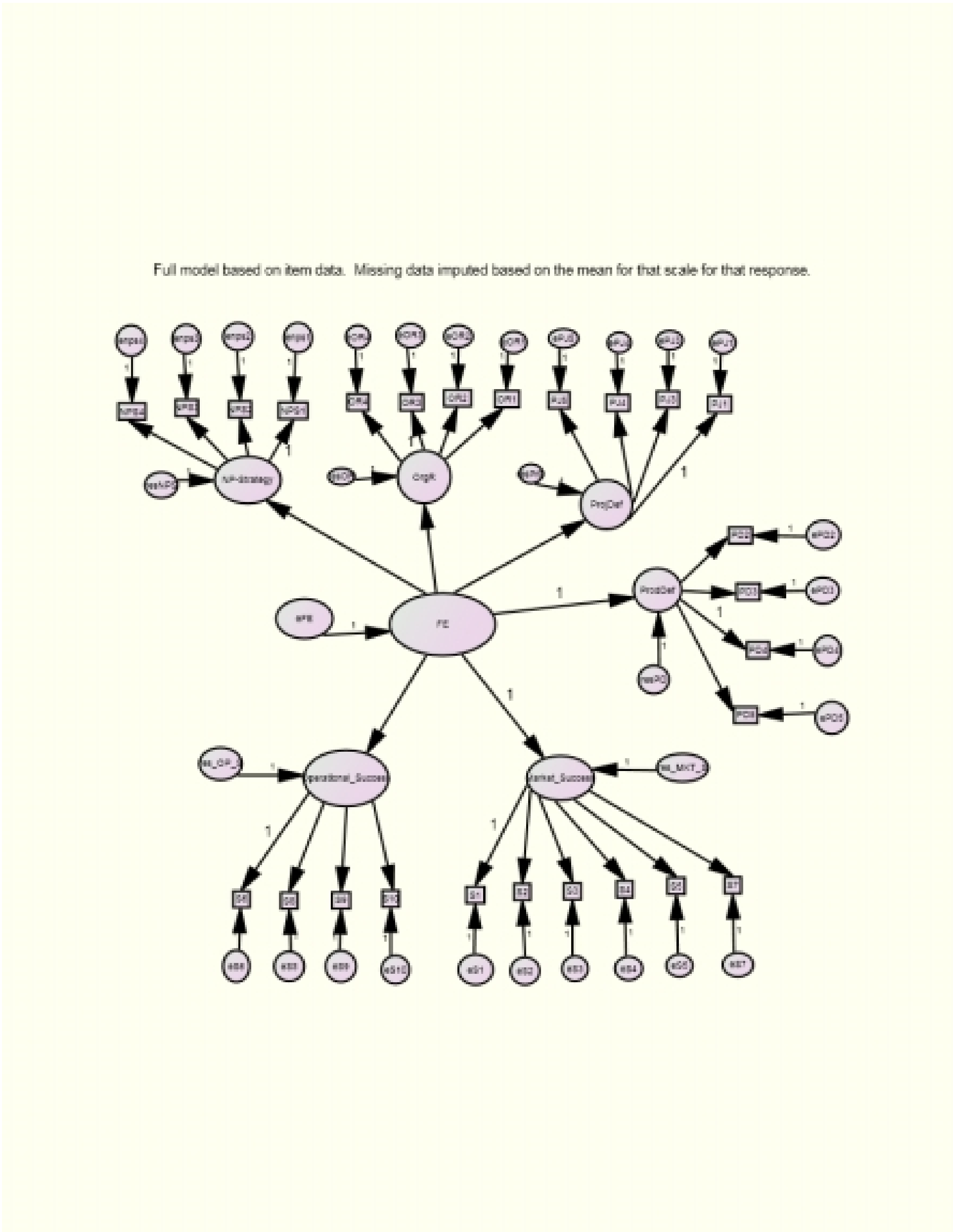
Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	-0.82229	0.20044	-4.10	<.0001*	-1.2187	-0.42584	0
NPS	0.298573	0.11779	2.53	0.0124*	0.06559	0.531549	0.20063
Prod_Def	0.018538	0.09895	0.19	0.8517	-0.17718	0.214262	0.01474
Proj_Def	0.668975	0.13036	5.13	<.0001*	0.41114	0.926806	0.42570
Org_Roles	0.248154	0.12958	1.91	0.0576	-0.00814	0.50445	0.16199

Residual by Predicted Plot



Appendix N

Full Model SEM Analysis



Standardized Regression Weights: (Base model)

			Estimate
Operational_Success	<---	FE	.730
Market_Success	<---	FE	.852
NP_Strategy	<---	FE	.603
OrgR	<---	FE	.761
ProjDef	<---	FE	.816
ProdDef	<---	FE	.719
S1	<---	Market_Success	.739
S2	<---	Market_Success	.826
S3	<---	Market_Success	.783
S7	<---	Market_Success	.407
NPS1	<---	NP_Strategy	.904
PD2	<---	ProdDef	.820
PD3	<---	ProdDef	.723
PD4	<---	ProdDef	.785
PD5	<---	ProdDef	.593
NPS3	<---	NP_Strategy	.608
NPS2	<---	NP_Strategy	.818
S10	<---	Operational_Success	.746
S9	<---	Operational_Success	.835
S8	<---	Operational_Success	.848
S6	<---	Operational_Success	.849
S5	<---	Market_Success	.747
S4	<---	Market_Success	.669
NPS4	<---	NP_Strategy	.639
OR4	<---	OrgR	.861
OR3	<---	OrgR	.653
OR2	<---	OrgR	.727
OR1	<---	OrgR	.708
PJ4	<---	ProjDef	.682
PJ5	<---	ProjDef	.540
PJ1	<---	ProjDef	.503
PJ3	<---	ProjDef	.859

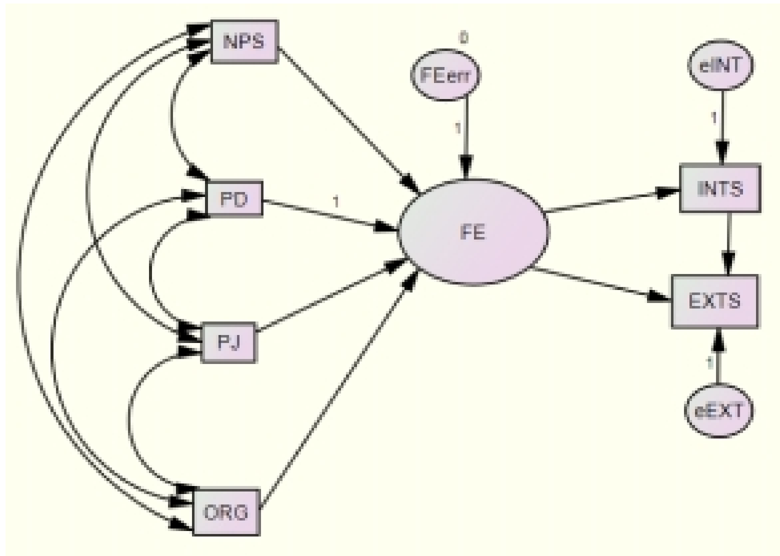
Alternative Full Model SEM Comparisons

Alternate models were run correlating error variables based on high modification indices and acceptable theoretical relationships. Below table contains the model parameters and the GoF comparisons.

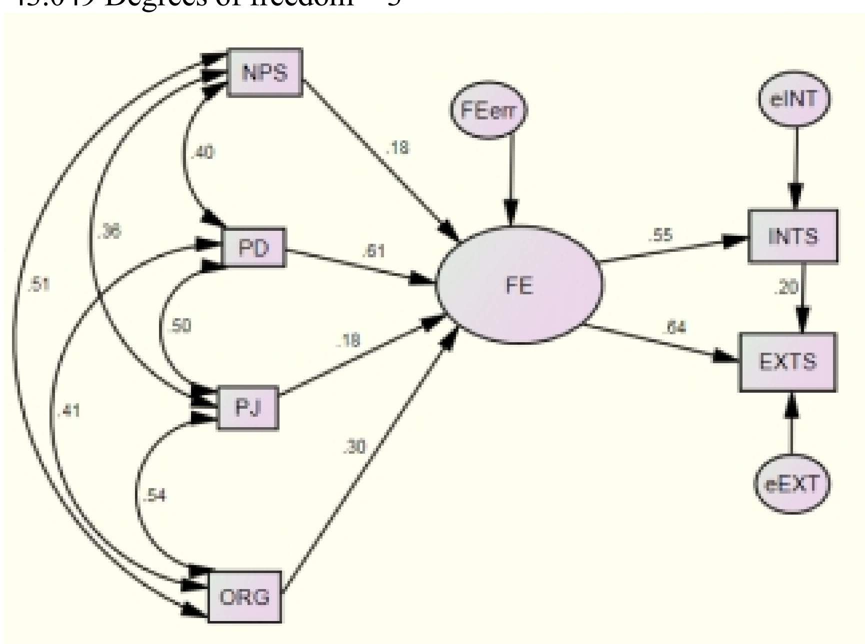
Model	Differences	GoF Comparisons
Base model	None, this is the default picture above	CMIN/DF 2.720 GFI .711 NFI .697 CFI .781 PRATIO .905 PNFI .630 PCFI .707 RMSEA .107
Model2-MI-a	Models largest MI on covariance from the base model - res_MKT_S <--> resPD = 31.23	Fit is slightly better CMIN/DF 2.574 GFI .733 NFI .714 CFI .801 PRATIO .902 PNFI .644 PCFI ..722 RMSEA .102
Model2-MI-b	res_MKT_S <--> resPD = 31.23 AND eOR2<-->eOR1 17.113 .202	CMIN/DF 2.511 GFI .743 NFI .722 CFI .809 PRATIO .898 PNFI .649 PCFI .727 RMSEA .100
Model2-MI-C	res_MKT_S <--> resPD = 31.23 AND eOR2<-->eOR1 17.113 .202 AND eS9<-->eS8 11.611 .334	Best fit. CMIN/DF 2.451 GFI . 751 NFI .730 CFI .817 PRATIO .895 PNFI .653 PCFI .732 RMSEA .098

Appendix O

SEM Model Internal Success Predicting External Success



Minimum was achieved
Chi-square = 43.049 Degrees of freedom = 3



Regression Weights:

			Estimate	S.E.	C.R.	P	Label
FE	<---	PD	1.000				
FE	<---	ORG	.595	.200	2.978	.003	par_1
FE	<---	PJ	.369	.201	1.836	.066	par_9
FE	<---	NPS	.358	.174	2.055	.040	par_10
INTS	<---	FE	.221	.037	5.954	***	par_11
EXTS	<---	INTS	.279	.087	3.204	.001	par_8
EXTS	<---	FE	.358	.054	6.637	***	par_12

Standardized Regression Weights:

			Estimate
FE	<---	PD	.608
FE	<---	ORG	.296
FE	<---	PJ	.177
FE	<---	NPS	.183
INTS	<---	FE	.554
EXTS	<---	INTS	.200
EXTS	<---	FE	.642

CMIN/DF	14.35
GFI	.924
NFI	.889
CFI	.893
PRATIO	.200
RMSEA	.297

Appendix P

Moderating Effect of Innovation on Success

Effect of Front-end Variables on Internal (Operational-based) Success with Moderating Variable of Innovation Level

Model 1: F(α, 1, 133)
Full Model Predictors: Constant, NPS, PD, PJ, OR, INN (p = 4 + 1)

Reduced Model Predictors: Constant, NPS, PD, PJ, OR (q=4)

Model 2: F(α, 4, 129)
Full Model Predictors: Constant, NPS, PD, PJ, OR, NPS*INN, PD*INN, PJ*INN, OR*INN, INN
(p= 4 + 4 + 1 = 9)

Reduced Model Predictors: Constant, NPS, PD, PJ, OR, INN (q= 4 + 1 = 5)

		Unstandardized				
Model	**Term**	**Beta**	**Std Error**	**Std Beta**	**t Ratio**	**Prob>|t|**
1	Intercept	-0.8409	0.1920	0	-4.38	<.0001*
	NPS	0.30617	0.1128	0.2057	2.71	0.0075*
	Prod_Def	0.09374	0.0970	0.07457	0.97	0.3356
	Proj_Def	0.59046	0.1266	0.37574	4.66	<.0001*
	Org_Roles	0.22273	0.1243	0.14539	1.79	0.0754
	Inn-Level[0]	0.37972	0.1046	0.2346	3.63	0.0004*
2	Intercept	-0.76642	0.1883	0	-4.07	<.0001*
	NPS	0.71194	0.1455	0.4784	4.89	**<.0001***
	Prod_Def	-0.04215	0.1112	-0.033	-0.38	0.7053
	Proj_Def	0.53683	0.1440	0.3416	3.73	**0.0003***
	Org_Roles	-0.00252	0.1509	-0.0016	-0.02	0.9867
	NPS*Inv	-0.87878	0.2173	-0.5063	-4.04	**<.0001***
	PD*Inv	0.31964	0.2124	0.1925	1.50	0.1348
	PJ*Inv	0.12517	0.2655	0.0623	0.47	0.6381
	OR*Inv	0.36658	0.2536	0.2232	1.45	0.1507
	Inn-Level[0]	0.34781	0.1883	0.2148	1.85	0.0671

N = 139
Dummy Variable Coding NTC = 1 AEL and PI = 0

Partial F results

Model	R^2	R^2 Change	F Change	Partial F Value	Sig F Change
1	0.4794	0.0516	-0.555	13.182	0.001
2	0.5435	0.0641	-7.433	4.528	0.005

Partial F Test Calculations for Moderated Multiple Regression

$F= [(R^2p - R^2q) / (p - q)] / [(1 - R^2p) ((n- p - 1)]$

Dummy Variable Partial F Test (Innovation Level):

Full Model $R^2p = 0.4794$
Reduced Model $R^2q = 0.4278$

$F= (0.4794 - 0.4278)/(5-4)$
$(1 - 0.4794)/(139 - 5 - 1)$

Full Model p=4+1=5
Reduced Model q=4

df = (p – q), (n – p - 1)
F= 13.1824; p< .001; df = 1, 133

F (Table) = F(.001, 1, 133) = 11.324
Null hypothesis is rejected.

Dummy Cross Products Partial F Test

Full Model $R^2p = 0.5435$
Reduced Model $R^2q = 0.4794$

Sample calculations:
$F= (0.5435 - 0.4794)/(9 - 5)$
$(1 - 0.5435)/(139 - 9 - 1)$

FM p=4+1+4=9
RM q=4+1=5

df = (p – q), (n – p - 1)
F= 4.5284; p< .005; df = 4, 129

F (Table) = F(.005, 4, 129) = 3.906 p< .005
F (Table) = F(.001, 4, 129) = 4.923

Response Internal Success

Model 1: F(α, 1, 133)

Full Model Predictors: Constant, NPS, PD, PJ, OR, INN (p = 4 + 1)

Summary of Fit

RSquare	0.4794
RSquare Adj	0.45983
Root Mean Square Error	1.1713
Mean of Response	0.77518
Observations (or Sum Wgts)	139

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	168.04798	33.6096	24.4951
Error	133	182.48889	1.3721	**Prob > F**
C. Total	138	350.53687		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta
Intercept	-0.8409	0.191989	-4.38	<.0001*	0
NPS	0.30617	0.11280	2.71	0.0075*	0.2057
Prod_Def	0.09374	0.09699	0.97	0.3356	0.07457
Proj_Def	0.59046	0.12667	4.66	<.0001*	0.37574
Org_Roles	0.22273	0.12427	1.79	0.0754	0.14539
Inn-Level[0]	0.37972	0.10463	3.63	0.0004*	0.2346

Response Internal Success

Model 1: F(α, 1, 133)
Reduced Model Predictors: Constant, NPS, PD, PJ, OR (q=4)

Summary of Fit

RSquare	0.427844
RSquare Adj	0.410765
Root Mean Square Error	1.223409
Mean of Response	0.77518
Observations (or Sum Wgts)	139

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	149.97504	37.4938	25.0504
Error	134	200.56183	1.4967	**Prob > F**
C. Total	138	350.53687		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta
Intercept	-0.822293	0.200447	-4.10	<.0001*	0
NPS	0.2985733	0.117794	2.53	0.0124*	0.200637
Prod_Def	0.018538	0.098959	0.19	0.8517	0.014748
Proj_Def	0.6689756	0.130361	5.13	<.0001*	0.425707
Org_Roles	0.2481541	0.129585	1.91	0.0576	0.161992

Response Internal Success

Model 2: F(α, 4, 129)
Full Model Predictors: Constant, NPS, PD, PJ, OR, NPS*INN, PD*INN, PJ*INN, OR*INN, INN (p= 4 + 4 + 1 = 9)
Reduced Model Predictors: Constant, NPS, PD, PJ, OR, INN (q= 4 + 1 = 5)

Summary of Fit

RSquare	0.543461
RSquare Adj	0.511609
Root Mean Square Error	1.11381
Mean of Response	0.77518
Observations (or Sum Wgts)	139

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	190.50303	21.1670	17.0623
Error	129	160.03384	1.2406	**Prob > F**
C. Total	138	350.53687		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta
Intercept	-0.766425	0.188322	-4.07	<.0001*	0
NPS	0.711941	0.145508	4.89	<.0001*	0.478415
Prod_Def	-0.042148	0.111187	-0.38	0.7053	-0.03353
Proj_Def	0.5368272	0.144045	3.73	0.0003*	0.341613
Org_Roles	-0.002517	0.150952	-0.02	0.9867	-0.00164
NPS*Inv	-0.878781	0.217297	-4.04	<.0001*	-0.50628
PD*Inv	0.3196415	0.212419	1.50	0.1348	0.192548
PJ*Inv	0.125174	0.265529	0.47	0.6381	0.062361
OR*Inv	0.3665811	0.253596	1.45	0.1507	0.223231
Inn-Level[0]	0.3478087	0.188322	1.85	0.0671	0.214847

Effect of Front-end Variables on External (Market-based) Success with Moderating Variable of Innovation Level

Model 1: F(α, 1, 132)
Full Model Predictors: Constant, NPS, PD, PJ, OR, INN (p = 4 + 1)

Reduced Model Predictors: Constant, NPS, PD, PJ, OR (q=4)

Model 2: F(α, 4, 128)
Full Model Predictors: Constant, NPS, PD, PJ, OR, NPS*INN, PD*INN, PJ*INN, OR*INN, INN
(p= 4 + 4 + 1 = 9)

Reduced Model Predictors: Constant, NPS, PD, PJ, OR, INN (q= 4 + 1 = 5)

		Unstandardized				
Model	**Term**	**Beta**	**Std Error**	**Std Beta**	**t Ratio**	**Prob>|t|**
1	Intercept	-0.8409	0.1920	0	-4.38	<.0001*
	NPS	0.30617	0.1128	0.2057	2.71	0.0075*
	Prod_Def	0.09374	0.0970	0.07457	0.97	0.3356
	Proj_Def	0.59046	0.1266	0.37574	4.66	<.0001*
	Org_Roles	0.22273	0.1243	0.14539	1.79	0.0754
	Inn-Level[0]	0.37972	0.1046	0.2346	3.63	0.0004*
2	Intercept	-0.082038	0.12874	0	-0.64	0.5251
	NPS	0.2303281	0.099461	0.210138	2.32	0.0222*
	Prod_Def	0.445436	0.076002	0.479657	5.86	<.0001*
	Proj_Def	0.1076931	0.098461	0.093046	1.09	0.2761
	Org_Roles	0.1982797	0.103183	0.175663	1.92	0.0569
	NPS*Inv	-0.255221	0.148685	-0.19882	-1.72	0.0885
	PD*Inv	0.3295973	0.14892	0.269073	2.21	0.0287*
	PJ*Inv	-0.379964	0.181847	-0.25657	-2.09	0.0386*
	OR*Inv	0.0533597	0.174913	0.043789	0.31	0.7608
	Inn-Level[0]	-0.191164	0.12874	-0.15949	-1.48	0.1400

N = 138
Dummy Variable Coding NTC = 1 AEL and PI = 0

Model	R^2	R^2 Change	F Change	Partial F Value	Sig F Change
1	0.5831	0.0008	-9.413	0.2533	N.S.
2	0.6097	0.0266	-14.719	2.249	0.1

1: Full Model Predictors: Constant, NPS, PD, PJ, OR, INN

Reduce Model Predictors: Constant, NPS, PD, PJ, OR

2: Full Model Predictors: Constant, NPS, PD, PJ, OR, NPS*INN, PD*INN, PJ*INN, OR*INN, INN

Reduced Model Predictors: Constant, NPS, PD, PJ, OR, INN

Partial F Test Calculations for Moderated Multiple Regression

$F= [(R^2_p - R^2_q) / (p - q)] / [(1 - R^2_p) ((n- p - 1)]$

Dummy Variable Partial F Test (Innovation Level):

Full Model R^2_p = 0.5831
Reduced Model R^2_q = 0.5823

$$F= \frac{(0.5831 - 0.5823)/(5-4)}{(1 - 0.5831)/(138 - 5 - 1)}$$

FM p=4+1=5
RM q=4

df = (p – q), (n – p - 1)
F= 0.2533; df = 4, 132, n.s.

Fail to reject Ho. Continue to cross product terms

Effect of innovation as a moderator variable is not significant.

Cross Products Partial F Test

Full Model R^2p = 0.6097

Reduced Model R^2q = 0.5831

$$F = \frac{(0.6097 - 0.5831)/(9-5)}{(1 - 0.6097)/(138 - 9 - 1)}$$

FM p=4+4+1=9

RM q=4+1=5

df = (p – q), (n – p - 1)

F= 2.249; df = 4, 128

F (Table) = F(.1, 4, 128) = 1.99

F (Table) = F(.05, 4, 128) = 2.44

Reject Ho. Cross product terms show a moderator effect.

Significant cross product effect at 0.05 < p < 0.1. Alpha set a priori at 0.05, therefore no significant moderation effect on external success.

Response External Success

Summary of Fit

RSquare	0.583183
RSquare Adj	0.567394
Root Mean Square Error	0.774778
Mean of Response	0.929952
Observations (or Sum Wgts)	138

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	110.86346	22.1727	36.9371
Error	132	79.23719	0.6003	**Prob > F**
C. Total	137	190.10064		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta
Intercept	-0.14171	0.127023	-1.12	0.2666	0
NPS	0.1244015	0.074639	1.67	0.0979	0.113497
Prod_Def	0.5262109	0.06464	8.14	<.0001*	0.566637
Proj_Def	0.0093951	0.0838	0.11	0.9109	0.008117
Org_Roles	0.2598816	0.082335	3.16	0.0020*	0.230238
Inn-Level[0]	-0.037203	0.06977	-0.53	0.5948	-0.03104

Response External Success

Summary of Fit

RSquare	0.582285
RSquare Adj	0.569722
Root Mean Square Error	0.772691
Mean of Response	0.929952
Observations (or Sum Wgts)	138

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	110.69278	27.6732	46.3498
Error	133	79.40787	0.5971	**Prob > F**
C. Total	137	190.10064		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta
Intercept	-0.143708	0.126625	-1.13	0.2585	0
NPS	0.1249952	0.07443	1.68	0.0954	0.114038
Prod_Def	0.5339972	0.062799	8.50	<.0001*	0.575022
Proj_Def	0.0017317	0.082336	0.02	0.9833	0.001496
Org_Roles	0.2571073	0.081949	3.14	0.0021*	0.22778

Response External Success

Summary of Fit

RSquare	0.609713
RSquare Adj	0.582271
Root Mean Square Error	0.76134
Mean of Response	0.929952
Observations (or Sum Wgts)	138

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	115.90688	12.8785	22.2182
Error	128	74.19377	0.5796	**Prob > F**
C. Total	137	190.10064		<.0001*

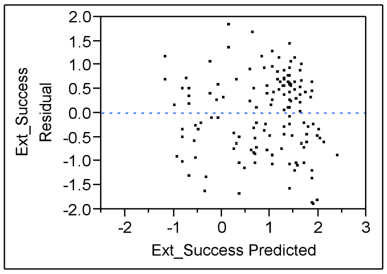
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta
Intercept	-0.082038	0.12874	-0.64	0.5251	0
NPS	0.2303281	0.099461	2.32	0.0222*	0.210138
Prod_Def	0.445436	0.076002	5.86	<.0001*	0.479657
Proj_Def	0.1076931	0.098461	1.09	0.2761	0.093046
Org_Roles	0.1982797	0.103183	1.92	0.0569	0.175663
NPS*Inv	-0.255221	0.148685	-1.72	0.0885	-0.19882
PD*Inv	0.3295973	0.14892	2.21	0.0287*	0.269073
PJ*Inv	-0.379964	0.181847	-2.09	0.0386*	-0.25657
OR*Inv	0.0533597	0.174913	0.31	0.7608	0.043789
Inn-Level[0]	-0.191164	0.12874	-1.48	0.1400	-0.15949

Appendix Q

Internal Success Item Regression on External Success

Residual by Predicted Plot



Summary of Fit

RSquare	0.53504
RSquare Adj	0.52221
Root Mean Square Error	0.80042
Mean of Response	0.94667
Observations (or Sum Wgts)	150

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	106.898	26.72	41.71
Error	145	92.897	0.641	**Prob > F**
C. Total	149	199.796		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	Lower 95%	Upper 95%	Std Beta
Intercept	0.47136	0.08329	5.66	<.0001*	0.3067	0.6359	0
Q7S6I_Time2Mkt	0.34531	0.05729	6.03	<.0001*	0.2320	0.4585	0.54589
Q7S8I_prjschd	-0.22597	0.06341	-3.56	0.0005*	-0.3512	-0.1006	-0.3634
Q7S9I_prjbud	-0.02101	0.06199	-0.34	0.7351	-0.1435	0.1015	-0.03290
Q7S10E_projscope	0.36844	0.05398	6.83	<.0001*	0.2617	0.4751	0.53443

REFERENCES

Adams, M. (2004). The PDMA Foundation's Comparative Performance Assessment Study (CPAS) Results. Comparative Performance Assessment Conference, New Orleans, LA, Product Development Management Association (PDMA).

Adams, M. E., G. S. Day, et al. (1998). "Enhancing New Product Development Performance: An Organizational Learning Perspective." Journal of Product Innovation Management **15**: 403-422.

Akgün, A. E., G. S. Lynn, et al. (2006). "Antecedents and Consequences of Unlearning in New Product Development Teams." Journal of Product Innovation Management **23**(1): 73-88.

Anderson, D., R. C. Plotnikoff, et al. (2004). "Towards the Development of Scales to Measure 'will' to Promote Heart Health within Health Organizations in Canada." Health Promotion International **19**(4).

Annacchino, M. A. (2003). New Product Development: From Initial Idea to Product Management. Amsterdam, Elsevier.

Arensman, R. (2007). Electronic Business' Top 50 Semiconductor Companies: Reversal of Fortune? Electronic Design News. **May**.

Atuahene-Gima, K. and Y. Wei (2011). "The Vital Role of Problem-Solving Competence in New Product Success." Journal of Product Innovation Management **28**(1): 81–98.

Balachandra, R. and J. H. Friar (1997). "Factors for Success in R&D Projects and New Product Innovation: A Contextual Framework." IEEE Transactions on Engineering Management **44**(3).

Bart, C. and A. Pujari (2007). "The Performance Impact of Content and Process in Product Innovation Charters." Journal of Product Innovation Management **24**(1): 3-19.

Belliveau, P., A. Griffin, et al. (2002). The PDMA Toolbook for New Product Development. New York, John Wiley & Sons, Inc.

Black, L. J. (2002). Collaborating Across Boundaries: Theoretical, Empirical, and Simulated Explorations. Sloan School of Management. Boston, Massachusetts, Massachusetts Institute of Technology**:** 282.

Blunch, N. J. (2008). Introduction to Structural Equation Modeling Using SPSS and AMOS. London, Sage Publications Ltd.

Boike, D. and M. Adams (2004). PDMA Foundation CPAS Study Reveals New Trends - While the "Best-Rest" Gap Widens. Visions Magazine. 28, July 2004: 26-29.

Booz-&-Company (2010). Corporate R&D Spending Declined During 2009 Downturn, Finds Booz & Company Global Innovation Study, Booz & Company. **2011**.

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

Browne, M. W. and R. Cudeck (1993). Alternative Ways of Assessing Model Fit. Testing Structural Equation Models. K. A. Bollen and J. S. Long. Newsbury Park, CA, Sage**:** 136-162.

Buggie, F. D. (2002). "Set the "Fuzzy Front End" in Concrete." Research Technology Management **45**(4): 11-14.

Burns, T. and G. M. Stalker (1961). The Management of Innovation. London, Tavistock Publications.

Byrne, B. M. (2001). Structural Equation Modeling with AMOS. Basic Concepts, Applications, and Programming. New Jersey, Lawrence Erlbaum Associates.

Calantone, R., K. Chan, et al. (2006). "Decomposing Product Innovativeness and Its Effects on New Product Success." Journal of Product Innovation Management **23**: 408-421.

Calantone, R., C. A. DiBenedetto, et al. (1999). "Using the Anlaytic Hierarchy Process in New Product Screening." Journal of Product Innovation Management **16**(1): 65-76.

Calantone, R. J., C. A. DiBenedetto, et al. (1993). "Organisational, Technical and Marketing Antecedents for Successful New Product Development." R&D Management **23**(4): 337–351.

Calantone, R. J., J. B. Schmidt, et al. (1997). "New Product Activities and Performance: The Moderating Role of Environmental Hostility." Journal of Product Innovation Management **14**(3): 179–189.

Campbell, D. T. and J. Stanley (1963). Experimental and Quasi-Experimental Designs for Research, Wadsworth Publishing.

Carbone, T. A. (2004). Developing a New Survey Instrument for the Fuzzy Front End of New Product Development: The Agony and Ecstasy. American Society of Engineering Management Annual Conference, Alexandria, Virginia.

Carbone, T. A. (2005). Integrating Operations and Product Development Methodologies for Improved Product Success using Advanced Product Quality Planning. IEEE Advanced Semiconductor Manufacturing Conference, Munich, Germany, IEEE and SEMI.

Carbone, T. A. (2006). Personal Communication on Information Processing Theory. J. R. Galbraith.

Chatterjee, P. K. and R. R. Doering (1998). "The Future of Microelectronics." Proceedings of the IEEE **86**(1): 176 - 183.

Choo, C. W. (1991). "Towards an Information Model of Organizations." The Canadian Journal of Information Science **16**(3): 32-62.

Christensen, C. M., S. King, et al. (2008). The New Economics of Semiconductor Manufacturing. IEEE Spectrum. **45:** 24-29.

Churchill, G. A. (1979). "A Paradigm for Developing Better Measures of Marketing Constructs." Journal of Marketing Research **16**: 64-73.

Clark, K. B. and S. C. Wheelwright (1993). Managing New Product and Process Development.

Clausing, D. (1994). Total Quality Development. A Step-By-Step Guide to World-Class Concurrent Engineering. New York, ASME Press.

Cohen, R. (2002). Exercises in Psychological Testing and Assessment. Boston, McGraw Hill.

Colarelli-O'Connor, G. and R. W. Veryzer (2001). "The Nature of Market Visioning for Technology-based Radical Innovation." Journal of Product Innovation Management **18**(4): 231–246.

Connell, J., G. C. Edgar, et al. (2001). "Troubling Successes and Good Failures: Successful New Product Development Requires Five Critical Factors." Engineering Management Journal **13**(4): 35-39.

Cooper, R. G. (1985). "Selecting Winning New Product Projects Using the NewProd System." Journal of Product Innovation Management **2**: 34-44.

Cooper, R. G. (1994). "Debunking the Myths of New Product Development." Research Technology Management **37**(4): 40-50.

Cooper, R. G. (1997). "Fixing the Fuzzy Front End of the New Product Development Process. Building the Business Case." CMA Management **71**(8): 21-23.

Cooper, R. G. (2001). Winning at New Products: Accelerating the Process from Idea to Launch. New York, Basic Books.

Cooper, R. G., S. J. Edgett, et al. (1997). "Portfolio Management in New Product Development: Lessons from the Leaders - I." Research Technology Management **40**(5): 16-28.

Cooper, R. G., S. J. Edgett, et al. (1997). "Portfolio Management in New Product Development: Lessons from the Leaders - II." Research Technology Management **40**(6): 43-52.

Cooper, R. G., S. J. Edgett, et al. (2002a). "Optimizing the Stage-Gate Process: What Best-Practice Companies Do - I." Research Technology Management **45**(5): 21-27.

Cooper, R. G., S. J. Edgett, et al. (2002b). "Optimizing the Stage-Gate Process: What Best-Practice Companies Do - II." Research Technology Management **45**(6): 43-49.

Cooper, R. G. and E. J. Kleinschmidt (1986). "An Investigation into the New Product Process: Steps, Deficiencies, and Impact." Journal of Product Innovation Management **3**: 71-85.

Cooper, R. G. and E. J. Kleinschmidt (1987). "New Products: What Separates Winners from Losers?" Journal of Product Innovation Management **4**(3): 169-184.

Cooper, R. G. and E. J. Kleinschmidt (1988). "Resource Allocation in the New Product Process." Industrial Marketing Management **17**: 249-262.

Cooper, R. G. and E. J. Kleinschmidt (1996). "Winning Businesses in Product Development: The Critical Success Factors." Research Technology Management **39**(4): 18-29.

Couillard, J. (1995). "The Role of Project Risk in Determining Project Management Approach." Project Management Journal (December): 3-15.

Cristiano, J. J., J. K. Liker, et al. (2000). "Customer-Driven Product Development Through Quality Function Deployment in the U.S. and Japan." Journal of Product Innovation Management **17**(4): 286–308.

Cronbach, L. and P. Meehl (1955). "Construct Validity in Psychological Tests." Psychological Bulletin **52**(4): 281-302.

de Brentani, U. (1986). "Do Firms Need a Custom-Designed New Product Screening Model?" Journal of Product Innovation Management **3**: 108-119.

DeGeus, A. P. (1988). "Planning as Learning." Harvard Business Review **66** (March/April): 70-74.

Doney, P. M. and J. P. Cannon. (1997). "An Examination of the Nature of Trust in Buyer-Seller Relationships." Journal of Marketing Management **61**(2): 35-51.

Dorval, K. B. and K. J. Lauer (2004). The Birth of Novelty: Ensuring New Ideas Get a Fighting Chance. The PDMA Toolbook for New Product Development. P. Belliveau, A. Griffin and S. Somermeyer. New York, John Wiley & Sons, Inc.

Dougherty, D. (1992). "A Practice-Centered Model of Organizational Renewal Through Product Innovation." Strategic Management Journal **13** (Summer Special Issue): 77-92.

Droge, C., R. Calantone, et al. (2008). "New Product Success: Is It Really Controllable by Managers in Highly Turbulent Environments?" Journal of Product Innovation Management **25**(3): 272-286.

Dutton, J. J. (1998). Target Setting: Key to Successful NPD Outcomes. PDMA Visions Magazine. **April**.

Dwyer, L. and R. Mellor (1991). "New Product Pocess Activities and Project Outcomes." R&D Management **21**(1): 31–42.

Ettlie, J. E. (1997). "Integrated Design and New Product Success." Journal of Operations Management **15**(1): 33-55.

Ettlie, J. E. and J. M. Elsenbach (2007). "Modified Stage-Gate Regimes in New Product Development." Journal of Product Innovation Management **24**: 20-33.

Faems, D., B. V. Looy, et al. (2005). "Interorganizational Collaboration and Innovation: Toward a Portfolio Approach." Journal of Product Innovation Management **22**(3): 238-250.

Fan, X., B. Thompson, et al. (1999). "Effects of Sample Size, Estimation Method, and Model Specification on Structural Equation Modeling Fit Indexes." Structural Equation Modeling **6**: 56-83.

Flint, D. J. (2002). "Compressing New Product Success-to-Success Cycle Time: Deep Customer Value Understanding and Idea Generation." Industrial Marketing Management **31**(4): 305-315.

Fowler, F. J. (1984). Survey Research Methods. Beverly Hills, Sage Publications.

Friedman, H. H. and T. Amoo (1999). "Rating the Rating Scales." Journal of Marketing Management **9**(3): 114-123.

Galbraith, J. R. (1973). Designing Complex Organizations. Reading, MA., Addison-Wesley.

Galbraith, J. R. (1977). Organization Design. Reading, Addison-Wesley.

Griffin, A. (1997). "PDMA Research on New Product Development Practices: Updating Trends and Benchmarking Best Practices." Journal of Product Innovation Management **14**: 429-458.

Griffin, A. (2002). "Product Development Cycle Time for Business-to-Business Products." Industrial Marketing Management **31**(4): 291-304.

Griffin, A. and J. R. Hauser (1996). "Integrating R&D and Marketing: A Review and Analysis of the Literature." Journal of Product Innovation Management **13**: 191-215.

Griffin, A. and A. Page (1996). "PDMA Success Measurement Project: Recommended Measures for Product Development Success and Failure." Journal of Product Innovation Management **13**(6): 478-496.

Griffin, A., R. L. Price, et al. (2009). "Voices from the Field: How Exceptional Electronic Industrial Innovators Innovate." Journal of Product Innovation Management **26**(2): 222–240.

Hair, J. F., R. L. Tatham, et al. (1998). Multivariate Data Analysis. Upper Saddle River, NJ, Prentice Hall.

Hamilton, A. (2002). "Considering Value During Early Project Development: A Product Case Study." International Journal of Project Management **20**: 131-136.

Hauptman, O. and K. K. Hirji (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.

Hecker, D. E. (2005). "High-technology Employment: A NAICS-based Update." Monthly Labor Review **128**(7).

Highhouse, S. and J. Z. Gillespie (2009). Do Samples Really Matter That Much? Statistical and Methodological Myths and Urban Legends: Doctrine, Verity and Fable in the Organizational and Social Sciences. C. E. Lance and R. J. Vandenberg. New York, Routledge: 249-268.

Hoyle, R. H. (1995). Structural Equation Modeling. Concepts, Issues, and Applications. London, Sage Publications.

Hultink, E. J., S. Hart, et al. (2000). "Launch Decisions and New Product Success: An Empirical Comparison of Consumer and Industrial Products." Journal of Product Innovation Management **17**(1): 5–23.

IC-Insights-Inc. (2011). IC Insights: Semi Capex to Exceed $60 Billion, Semiconductor Manufacturing and Design Community.

Jassawalla, A. R. and H. C. Sashittal (2001). "The Role of Senior Management and Team Leaders in Building Collaborative New Product Teams." Engineering Management Journal **13**(2): 33-39.

Kahn, K. B., G. Castellion, et al., Eds. (2005). PDMA Handbook of New Product Development. New Jersey, John Wiley & Sons.

Kerzner, H. (2006). Project Management: A Systems Approach to Planning, Scheduling, and Controlling, John Wiley and Sons.

Khurana, A. and S. R. Rosenthal (1997). "Integrating the Fuzzy Front End of New Product Development." Sloan Management Review (Winter): 103-120.

Khurana, A. and S. R. Rosenthal (1998). "Towards Holistic "Front Ends" in New Product Development." Journal of Product Innovation Management **15**(1): 57-74.

Kim, J. and D. Wilemon (2002, b). "Strategic Issues in Managing Innovations Fuzzy Front End." European Journal of Innovation Management **5**(1): 27-39.

Kim, J. and D. Wilemon (2002a). "Strategic Issues in Managing Innovations Fuzzy Front End." European Journal of Innovation Management **5**(1): 27-39.

Kim, J. and D. Wilemon (2002b). "Focusing the Fuzzy Front-End in New Product Development." R & D Management **32**(4): 269-279.

Koen, P., G. Ajamian, et al. (2001). "Providing Clarity and a Common Language to the "fuzzy front end."" Research Technology Management **44**(2): 46-55.

Langerak, F., E. J. Hultink, et al. (2008). "Exploring Mediating and Moderating Influences on the Links among Cycle Time, Proficiency in Entry Timing, and New Product Profitability." Journal of Product Innovation Management **25**(4): 370-385.

Larson, E. W. and D. H. Gobeli (1988). "Organizing for Product Development Projects." Journal of Product Innovation Management **5**: 180-190.

Lawrence, P. R. and J. W. Lorsch (1967). "New Management Job: The Integrator." Harvard Business Review **45**(6): 142-152.

Lawrence, P. R. and J. W. Lorsch (1967). Organization and Environment: Managing Differentiation and Integration. Boston, Harvard University.

Lee, Y. and G. C. O'Connor (2003). "The Impact of Communication Strategy on Launching New Products: The Moderating Role of Product Innovativeness." Journal of Product Innovation Management **20**: 4-21.

Liginlal, D. (1999). Building Fuzzy Front-End Decision Support Systems for New Product Introduction in Global Telecommunication Markets: A Measure Theoretical Approach. Management. Tuscon, University of Arizona: 260.

Liker, J. K., P. D. Collins, et al. (1999). "Flexibility and Standardization: Test of a Contingency Model of Product Design-Manufacturing Integration." Journal of Product Innovation Management **16**(3): 248-267.

Lynn, G. S. and A. E. Akgun (2001). "Project Visioning: Its Components and Impact on New Product Success." Journal of Product Innovation Management **18**(6): 374–387.

Lynn, G. S. and A. E. Akgun (2003). "Launch Your New Products/Services Better, Faster." Research Technology Management **46**(3): 21-26.

Lynn, G. S. and R. R. Reilly (2003). Blockbusters : The Five Keys to Developing GREAT New Products. New York, HarperCollins.

Lynn, G. S., R. R. Reilly, et al. (2000). "Knowledge Management in New Product Teams: Practices and Outcomes." IEEE Transactions on Engineering Management **47**(2): 221 - 231.

Macher, J. T. (2001). Innovation, Organization and Performance in the Global Semiconductor Industry, University of California, Berkeley: 178.

Macher, J. T. and D. C. Mowery (2003). "Learning by Doing: An Empirical Study in Semiconductor Manufacturing." Journal of Product Innovation Management **20**(5): 391–410.

Manion, M. T. and J. Cherion (2009). "Impact of Strategic Type on Success Measures for Product Development Projects." Journal of Product Innovation Management **26**(1): 71–85.

Markham, S. K. (1998). "A Longitudinal Examination of How Champions Influence Others to Support Their Projects." Journal of Product Innovation Management **15**(6): 490-504.

Markham, S. K. and A. Griffin (1998). "The Breakfast of Champions: Associations Between Champions and Product Development Environments, Practices and Performance." Journal of Product Innovation Management **15**(5): 436-454.

McGrath, M. E. (1996). Setting the PACE in Product Development, A Guide to Product and Cycle-time Excellence. Burlington, MA, Elsevier.

McGrath, M. E. (2001). Product Strategy for High Technology Companies. New York, McGraw-Hill.

McGrath, M. E. (2004). Next Generation Product Development. New York, McGraw-Hill Co.

Meyers, P. W. and D. Wilemon (1989). "Learning in New Technology Development Teams." Journal of Product Innovation Management **6**(1): 79-88.

Millson, M. R. and D. Wilemon (2002). "The Impact of Organizational Integration and Product Development Proficiency on Market Success." Industrial Marketing Management **31**(1): 1-23.

Moenaert, R. K., A. DeMeyer, et al. (1995). "R&D/Marketing Communication During the Fuzzy Front End." IEEE Transactions on Engineering Management **42**(3): 243-255.

Montoya-Weiss, M. M. and R. Calantone (1994). "Determinants of New Product Performance: A Review and Meta-Analysis." Journal of Product Innovation Management **11**(5): 397-417.

Montoya-Weiss, M. M. and T. M. O'Driscoll (2000). "From Experience: Applying Performance Support Technology in the Fuzzy Front End." Journal of Product Innovation Management **17**(2): 143-161.

Morgan, J. M. (2002). High Performance Product Development: A Systems Approach to a Lean Product Development Process. Industrial and Operations Engineering, University of Michigan.

Moris, F. A. (1996). "Semiconductors: The Building Blocks of the Information Revolution." Monthly Labor Review **119**(8).

Nobelius, D. and L. Trygg (2002). "Stop Chasing the Front End Process - Management of the Early Phases in Product Development Projects." International Journal of Project Management **20**: 331-340.

Nunnally, J. C. and I. H. Bernstein (1994). Psychometric Theory. New York, McGraw-Hill, Inc.

Olson, E. M., O. C. Walker, et al. (2001). "Patterns of Cooperation During New Product Development Among Marketing, Operations and R&D: Implications for Project Performance." Journal of Product Innovation Management **18**(4): 258-271.

Ottum, B. D. (1994). The Role of Market Information in New Product Success/Failure, University of Utah: 263.

Ottum, B. D. and W. L. Moore (1997). "The Role of Market Information in New Product Success/Failure." Journal of Product Innovation Management **14**(4): 258-273.

Ozer, M. and U. Cebeci (2010). "The Role of Globalization in New Product Development." IEEE Transactions on Engineering Management **57**(2): 168-180.

Paladino, A. (2007). "Investigating the Drivers of Innovation and New Product Success: A Comparison of Strategic Orientations." Journal of Product Innovation Management **24**: 534-553.

Paul, R. N. (1996). Evaluating Ideas and Concepts for New Business-To-Business Products. The PDMA Handbook of New Product Development. M. D. Rosenau, A. Griffin, G. A. Castellion and N. F. Anschuetz, John Wiley & Son, Inc.: 207-216.

Podsakoff, P. M., M. Ahearne, et al. (1997). "Organizational Citizenship Behavior and the Quantity and Quality of Work Group Performance." Journal of Applied Psychology **82**(2): 262-270.

Poolton, J. and I. Barclay (1998). "New Product Development From Past Research to Future Applications." Industrial Marketing Management **27**(3): 197-212.

Project-Management-Institute (2004). A Guide to the Project Management Body of Knowledge. Newtown Square, PA, Project Management Institute.

Ragatz, G. L., R. B. Handfield, et al. (1997). "Success Factors for Integrating Suppliers into New Product Development." Journal of Product Innovation Management **14**(3): 190–202.

Reid, S. E. and U. de Brentani (2004). "The Fuzzy Front End of New Product Development for Discontinuous Innovations: A Theoretical Model." Journal of Product Innovation Management **21**: 170-184.

Reinertsen, D. G. (1999). "Taking the Fuzziness Out of the Fuzzy Front End." Research Technology Management **42**(6): 25-31.

Rice, M. P., R. Leifer, et al. (2002). "Commercializing Discontinuous Innovations: Bridging the Gap from Discontinuous Innovation Project to Operations." IEEE Transactions on Engineering Management **49**(4): 330 - 340.

Rosenau, M. D., A. Griffin, et al. (1996). The PDMA Handbook of New Product Development. New York, John Wiley & Sons, Inc.

Roth, P. L. and F. S. Switzer (1995). "A Monte Carlo Analysis of Missing Data Techniques in a HRM Setting." Journal of Management **21**(5): 1003-1023.

Rummler, G. A. and A. P. Brache (1995). Improving Performance. How to Manage the White Space on the Organization Chart. San Francisco, Jossey-Bass.

Sahay, A. and D. Riley (2003). "The Role of Resource Access, Market Considerations, and the Nature of Innovation in Pursuit of Standards in the New Product Development Process." Journal of Product Innovation Management **20**: 388-355.

Salomo, S., J. Weise, et al. (2007). "NPD Planning Activities and Innovation Performance: The Mediating Role of Process Management and the Moderating Effect of Product Innovativeness." Journal of Product Innovation Management **24**(4): 283-302.

Schafer, J. L. and J. W. Graham (2002). "Missing Data: Our View of the State of the Art." Psychological Methods **7**(2): 147-177.

Schmidt, J. B. and R. Calantone (1998). "Are Really New Product Development Projects Harder to Shut Down?" Journal of Product Innovation Management **15**(2): 111-123.

Schumacker, R. E. and R. G. Lomax (2004). A Beginner's Guide to Structural Equation Modeling. Mahwah, NJ, Lawrence Erlbaum Associates.

Seah, L. H. (2002). Implementation of Advanced Product Quality Planning (APQP) in a Semiconductor Assembly Plant. School of Mechanical and Production Engineering, Nanyang Technological University.

Semiconductor-Industry-Association (2008). SIA Annual Report. **2011**.

Shenhar, A. J., D. Dvir, et al. (2001). "Project Success: A Multidimensional, Strategic Concept." Long Range Planning **34**: 699-725.

Sherman, J. D., D. Berkowitz, et al. (2005). "New Product Development Performance and the Interaction of Cross-Functional Integration and Knowledge Management." Journal of Product Innovation Management **22**: 399-411.

Sherman, J. D., W. E. Souder, et al. (2000). " Differential Effects of the Primary Forms of Cross Functional Integration on Product Development Cycle Time." Journal of Product Innovation Management **17**(4): 257–267.

Simon, H. A. (1957). Models of Man - Social and Rational. New York, John Wiley.

Smith, P. G. and D. G. Reinertsen (1991). Developing Products in Half the Time. New York, Van Nostrand Reinhold.

Smith, P. G. and D. G. Reinertsen (1998). Developing Products in Half the Time: New Rules, New Tools. New York, John Wiley & Sons, Inc.

Sobek, D. K. (1997). Principles that Shape Product Development Systems: A Toyota-Chrysler Comparison. Industrial and Operations Engineering, University of Michigan.

Song, X. M. and M. E. Parry (1997). "The Determinants of Japanese New Product Successes." Journal of Marketing Research **34**(1): 64-76.

Song, X. M. and M. L. Swink (2009). "Marketing-Manufacturing Integration Across Stages of New Product Development: Effects on the Success of High-and Low-Innovativeness Products." IEEE Transactions on Engineering Management **56**(1): 31-44.

Souder, W. E. and R. K. Moenaert (1992). "Integrating Marketing and R&D Project Personnel within Innovation Projects: An Information Uncertainty Model." Journal of Management Studies **29**(4): 485-512.

Spanjol, J. (2003). Idea Generation in New Product Development: A Cognitive Framework of the Fuzzy Front End, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN: 298.

Spanjol, J. and F. Beuk (2007). The Early Bird Gets the Worm: Assessing Performance Across NPD Stages. Product Development Management Association Research Forum, Orlando, FL, PDMA.

Stamatis, D. H. (1998). Advanced Quality Planning. A Commonsense Guide to AQP and APQP. Porltand, Productivity Press, Inc.

Stevens, G. A. and J. Burley (1997). "3,000 Raw Ideas = 1 Commercial Success!" Research Technology Management **40**(3): 16-27.

Swink, M. L. and R. Calantone (2004). "Design-Manufacturing Integration as a Mediator of Antecendents to New Product Design Quality." IEEE Transactions on Engineering Management **51**(4): 472-482.

Switzer, F. S., P. L. Roth, et al. (1998). "Systematic Data Loss in HRM Settings: A Monte Carlo Analysis." Journal of Management **24**(6): 763-779.

Tatikonda, M. V. and M. M. Montoya-Weiss (2001). "Integrating Operations and Marketing Perspectives of Product Innovation: The Influence of Organizational Process Factors and Capabilities on Development Performance." Management Science **47**(1): 151-171.

Thompson, T. (2000). Risk Management Solutions for New Product Technologies in the Semiconductor Industry. Proceedings, 1st Austin Workshop on Engineering Management in Technology-Based Organizations, Austin, TX.

Tighe, G. (1998). "From Experience: Securing Sponsors and Funding for New Product Development Projects - The Human Side of Enterprise." Journal of Product Innovation Management **15**: 75-81.

Tzokas, N., E. J. Hultink, et al. (2004). "Navigating the New Product Development Process." Industrial Marketing Management **33**: 619-626.

Ullman, J. B. (2001). Structural Equation Modeling. Using Multivariate Statistics. B. G. T. L. S. Fidell. Needham Heights, MA, Allyn & Bacon: 653- 771.

Van-Der-Merwe, A. P. (2002). "Project Management and Business Development: Integrating Strategy, Structure, Processes and Projects." International Journal of Project Management **20**(5): 401-411.

Walko, J. (2008). Semi Industry to Spend $49.2B on R&D in '08. EE Times.

Ward, A. C. (2007). Lean Product and Process Development. Cambridge, The Lean Enterprise Insitute.

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

Yoo, D. K. and J. A. Park (2007). " Perceived Service Quality: Analyzing Relationships Among Employees, Customers, and Financial Performance." International Journal of Quality & Reliability Management **24**(9): 908 - 926.

Zahay, D., A. Griffin, et al. (2004). "Sources, Uses, and Forms of Data in the New Product Development Process." Industrial Marketing Management **33**(7): 657-666.

Zakrzewska-Bielawska, A. (2010). High Technology Company - Concept, Nature, Characteristics. The 4th WSEAS International Conference on Management, Marketing and Finances (MMF'10), Penang. Malaysia.

Zhang, Q. and W. J. Doll (2001). "The Fuzzy Front End and Success of New Product Development: A Causal Model." European Journal of Innovation Management **4**(2): 95-112.

Zirger, B. J. and M. A. Maidique (1990). "A Model of New Product Development: An Empirical Test." Management Science **36**(7): 867-883.