**ORGANIZATIONAL DIFFUSION OF INTEGRATED PRODUCT
DEVELOPMENT: DETERMINANTS AND PERFORMANCE CONSEQUENCES**

By

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ABSTRACT

Integrated product development (IPD) is an approach for developing new products focused on the early and active involvement of design, manufacturing, marketing, suppliers, customers, and other key new product development (NPD) stakeholders in order to achieve cross-functional integration and concurrent development of a product and its associated manufacturing processes. The benefits of integrated product development are well known in both the academic literature and popular press, with the most noteworthy of these benefits including significant reductions in new product development cycle time, product life-cycle costs, and engineering changes. In spite of these benefits, for the majority of manufacturing organizations, IPD is not used on 100% of NPD projects; thus raising the questions: i) what organizational contextual factors influence the extent of IPD diffusion within Canadian and American manufacturing organizations?, and ii) what is the relationship between how manufacturing organizations are using integrated product development and the performance they obtain?

These questions are explored by developing and testing a research model outlining the relationship between an innovative organizational climate, NPD strategy, NPD complexity, member support for IPD, practice diffusion difficulty (i.e., characteristics of an IPD practice that may limit its diffusion), extent of integrated product development diffusion (i.e., how integrated product development is used in the organization), communication quality (i.e., the extent that IPD improves the communication and integration of the functional disciplines involved in NPD), and new product development performance.

Results of 269 surveys from NPD managers indicate that the complexity of certain IPD practices and support for IPD directly influence IPD diffusion, while organizational climate and the complexity of the organization's product development activities indirectly influence IPD diffusion through IPD support. The findings also indicate that IPD diffusion directly influences communication quality but not NPD performance. Instead, IPD diffusion indirectly influences NPD performance through communication quality.

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CHAPTER I

INTRODUCTION

1.1 Preamble

New product development (NPD) is increasingly becoming a focal point in Canadian and American manufacturing organizations, as many such companies are, among other things, faced by rapidly changing consumer preferences, short lead times, and high rates of obsolescence. For these manufacturing organizations to successfully compete at both home and abroad, successful NPD is required. However, achieving successful NPD is a difficult, risky, and expensive endeavor. There are a number of ways that organizations are responding to the enormous challenge of successfully developing new products, including concurrent design and manufacturing activities, partnering with suppliers and customers, and including manufacturing in front-end concept and planning activities; just to name a few.

This research focuses on one of the ways of increasing the success rate of developing new products, specifically using integrated product development (IPD) in the organization's NPD projects. Integrated product development is an approach for "improving new product development performance (e.g., development time), which occurs in part through the overlap (partially or completely parallel execution) and the interaction (exchange of information) of certain activities in the NPD process" (Gerwin & Barrowman, 2002, p. 939).

The benefits of IPD are well known in the literature, including 24% - 60% reductions in NPD cycle time (Duffy & Salvendy, 1999; Ganapathy & Goh, 1997; Prasad, 1996), 15-50% reductions in product life-cycle costs, and 55-95% reductions in engineering changes (Ganapathy & Goh, 1997). However, in spite of these benefits, for the majority of manufacturing organizations, IPD is not used on 100% of NPD projects; thus raising the questions: i) why are some manufacturing organizations using IPD on every NPD project, while others are using IPD for a few key NPD projects or not at all? and ii) what is the relationship between how manufacturing organizations are using IPD and the performance they obtain?

1.2 Research Objectives

An innovation is an “idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers, 1983, p. 11). Innovation diffusion is therefore the process by which a new idea, practice, or object is “communicated through certain channels over time among members of a social system” (Rogers, 1983, p. 5). This process involves a number of stages, including initiation (i.e., finding a match between an innovation and its application in the organization), adoption (i.e., a decision is reached to invest the required resources for the diffusion of the innovation), adaptation (i.e., the innovation is available for use), acceptance (i.e., the innovation is used in organizational work), routinization (i.e., the innovation is encouraged as a normal activity), and infusion (i.e., the innovation is used to its fullest potential in the organization)(Cooper & Zmud, 1990).

The importance of examining the diffusion of innovations has been made clear in the literature. Tornatzky and Klein (1982), for example, in a meta-analysis of innovation characteristics and adoption, recommend that innovation studies should capture both adoption and implementation as dependent variables, and not simply adoption, in order to fully account for the diffusion process.

Although IPD can be considered a form of organizational innovation, recommendations such as those by Tornatzky and Klein (1982) have yet to be applied in any great effort to the study of integrated product development. The current IPD research literature fails to consider the major issues that may facilitate or hamper the extent of diffusion of IPD; giving the illusion to both managers and academics alike that since IPD considerably aids in successful NPD, it will naturally be used to its fullest extent in organizations. In reality however, IPD has yet to be infused by the large group of potential adopters, suggesting the presence of environmental (i.e., external to the organization), organizational contextual (i.e., internal to the organization but external to any one project team), and project (i.e., internal to the project team) factors slowing, or preventing, such infusion from occurring.

This research examines various organizational contextual factors that promote or inhibit the diffusion of IPD within Canadian and American manufacturers. As stated earlier, for diffusion to occur, an innovation must be communicated among the members of a social system. This social system can include, for example, a team, an organization (i.e., intra-organizational diffusion), multiple organizations (i.e., inter-organizational diffusion), or a

specific geographic area (e.g., city, province, country). This study addresses the intra-organizational diffusion (i.e., diffusion *within* an organization) of IPD¹, captured by the percentage of NPD projects undertaken by an organization during the past two years that used integrated product development.

The reason for studying organizational contextual factors versus team or environmental factors is best highlighted by Gerwin and Barrowman (2002) who, in a meta-analysis of IPD characteristics and NPD performance, conclude that few researchers have examined the effect of organizational context factors on project performance; a serious omission in the IPD research literature. The first objective of this study is stated as follows:

Research Objective

- Identify the organizational contextual determinants of IPD diffusion within Canadian and American manufacturers.

Organizations must have justification for diffusing integrated product development. For this research to be truly beneficial to Canadian and American manufacturers, analyzing the organizational contextual factors influencing the diffusion of IPD is not enough. The relationship between the diffusion of IPD and the type of performance obtained must also be examined. Identifying the relationship between IPD diffusion and performance is also important for researchers of integrated product development.

¹ Hereafter referred to as simply *IPD diffusion*

Gerwin and Barrowman (2002) indicate that studies of IPD do not adequately consider diffusion. As a result, the stage or extent of IPD diffusion becomes an uncontrolled variable that may effect results; which may in turn cause researchers to erroneously conclude that IPD is ineffective (e.g., low performance), when instead it is simply in an early stage of diffusion (e.g., adoption or adaptation).

Integrated product development performance measures the outcome of using IPD when developing new products. Such performance is captured by two separate constructs, specifically NPD performance and communication quality. New product development performance captures the commercial and technical success of a product and includes, for example, return-on-investment (ROI), development time reduction, conformance to quality standards, and reduction in engineering changes.

The overall goal of IPD is to improve the communication and integration of the functional disciplines involved in product development. In addition to measuring the financial and technical success of a product, how well IPD improves communication and integration must also be examined. Communication quality is the extent that IPD has improved the integration (i.e., the extent that functional disciplines involved in NPD work together and towards the same common goals) and communication (i.e., how well the various functional disciplines communicate with one another when developing new products) between the functional disciplines involved in NPD activities and includes, for example, the extent of open communication between the functional disciplines involved in NPD, the extent that the NPD goals are understood by the functional disciplines

involved in NPD, the extent by which NPD is viewed as a priority by the functional disciplines involved in NPD, and the extent that functional disciplines are involved in NPD activities. The second and third objectives of this research study aim to identify how IPD performance changes as the diffusion of IPD moves from the initiation stage through to the infusion stage within an organization.

Research Objectives

- Examine how NPD performance changes as IPD diffusion changes within Canadian and American manufacturers.
- Examine how communication quality changes as IPD diffusion changes within Canadian and American manufacturers.

1.3 Research Format

The remainder of this research study is presented over eight additional chapters. Chapter Two introduces and synthesizes the background material needed to understand and support the research model presented in Chapter Three. Chapter Two begins with an introduction to IPD and how it helps to increase the success of NPD efforts. The practices used to capture IPD for this research are then introduced and the relationship between these practices and NPD Performance is discussed. Attention then turns to reviewing the innovation and NPD literature in an attempt to identify possible factors influencing the extent of IPD diffusion. Chapter Two concludes with an overview of the measurements used to gauge NPD Performance.

Chapter Three develops a research model outlining the determinants and performance consequences of IPD diffusion in organizations. Chapter Three begins with an overview of the research and investigative questions for this study. Next, the research model is introduced and the major model components are discussed. Chapter Three concludes by presenting the hypotheses used to test the research model.

Chapter Four discusses the research methodology adopted by this study. Chapter Four begins by presenting the research instrument (i.e., questionnaire) and the sampling frame. This chapter then reports the results of a pilot study where a questionnaire was mailed to 490 managers of product development; of which 57 usable questionnaires were returned. Based on the returned questionnaires, the design of the research instrument and the internal consistency of model constructs are examined. Chapter Four concludes by discussing changes to the questionnaire based on the results of this analysis.

With the pilot study completed, 2010 managers of product development were mailed a revised questionnaire. Based on a total of 2500 mailed questionnaires (i.e., pilot study plus the full scale survey), 269 usable questionnaires were returned for an overall usable response rate of 11.1%. Chapter Five describes the process of collecting this data. Specific issues addressed in this chapter include the duration of the data collection process, the response rate, and reasons why managers may not have completed the questionnaire.

The organizations selected for this research are Canadian and American Manufactures possessing a primary North American Industry Classification System (NAICS) Code of 333 (i.e., Machinery Manufacturing), 334 (i.e., Computer and Electronic Product Manufacturing), 335 (i.e., Electrical Equipment, Appliance, and Component Manufacturing), or 336 (i.e., Transportation Equipment Manufacturing) and containing between 50 and 1000 employees. Chapter Six examines the characteristics of the organizations that actually responded to the questionnaire. Issues addressed in this chapter include the average size of responding organizations, types of NPD projects undertaken, and the extent of diffusion of IPD in these organizations.

Path analysis is adopted as the statistical technique to test the proposed model and develop a final model of IPD diffusion. Chapter Seven first focuses on testing any significant differences between the model components in terms of demographics (i.e., Canada versus the United States) and industrial sectors (i.e., NAICS Codes 333, 334, 335, 336). Next, attention turns to testing the various components of the proposed research model. Based on the results of this analysis, a revised model is developed to better explain the diffusion of IPD within organizations.

Chapter Eight discusses in detail the final research model developed in Chapter Seven. Issues discussed in this chapter include the similarities between the proposed and final research models, deviations between these models, why such deviation exists, new relationships identified in the final model but not in the original one, and the implications of the final model to researchers and managers. Throughout this chapter, qualitative data

is extensively used to further support the research findings and to identify and explore issues not addressed by the final research model or quantitative data.

Chapter Nine concludes this research study. The chapter begins by summarizing the study and its major findings. Next, the implications of the study and, more specifically, how this research makes a significant and original contribution to knowledge in the field of operations management are presented. Chapter Nine, and the research study, concludes with a discussion of the study's limitations and possible future initiatives for researchers interested in integrated product development.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Integrated product development is an approach for “improving new product development performance (e.g., development time), which occurs in part through the overlap (partially or completely parallel execution) and the interaction (exchange of information) of certain activities in the NPD process” (Gerwin & Barrowman, 2002, p. 939). Integrated product development helps to increase the speed of developing new products by shortening the NPD process, as well as preventing costly mistakes resulting from misunderstanding and conflict between the various functional disciplines (i.e., engineering, R&D, manufacturing, marketing) involved in developing new products (Badham, Couchman, & Zanko, 2000; Rusinko, 1999).

Many researchers praise the benefits of IPD citing 24% - 60% reductions in NPD cycle time (Duffy & Salvendy, 1999; Ganapathy & Goh, 1997; Prasad, 1996), 15-50% reductions in product life-cycle costs, and 55-95% reductions in engineering changes (Ganapathy & Goh, 1997). Integrated product development, however, offers many more advantages than simply reducing cycle time, development costs, and engineering changes. Calabrese (1999) suggests that IPD allows for the simplification of procedures that are focused on satisfying the needs of customers (e.g., by reducing the number of filters in the development process) and manufacturing and assembly (e.g., facilitating human interaction and decreasing the non-functional additions which often cause serious reliability problems), allowing for better choices involving the client’s expectations and the manufacturing capabilities of the organization.

Integrated product development also allows for increases in product quality, white-collar productivity, customer satisfaction, rationalization (e.g., designs considering the capabilities of the manufacturing system), overall input (e.g., relevant areas in addition to design and manufacturing are involved in the process), cross training (e.g., helps to reduce learning curves), use of scarce resources (e.g., people can be made available for the next project sooner if cycle time is reduced), and decreases in the occurrence of obsolesces (e.g., reduced time to market reduces occurrence of obsolesces) (Prasad, 1996).

2.2 Practices to Achieve Integrated Product Development

There are many practices an organization can use to achieve integrated product development. Such practices range in focus from people-based practices, such as cross-functional NPD teams, team rewards and physical co-location, to technology-based practices, such as CAD/CAM, common databases, and virtual co-location (e.g., Gerwin & Barrowman, 2002; Liker, Collins, & Hull, 1999; Poolton & Barclay, 1998; Trygg, 1993). The practices commonly used to achieve IPD are defined in Appendix 1.

To gain a better understanding of the relationship between IPD practices and NPD performance, researchers often combine similar practices into various categories. For example, Liker and Hull (1993) classify those practices used to achieve IPD into two major domains (i.e., organizational and technical initiatives) and five sub-domains (i.e., teams, design-manufacturing integration, training and group-based rewards, codification and standardization tools, and vertical information systems). Moffat (1998) identifies six “domain toolsets” labeled organizational tools and methods, simultaneity tools and

methods, computer-based design tools and methods, manufacturability tools and methods, development process standardization methods, and capturing customer requirements. Poolton and Barclay (1998) classify those practices used to achieve IPD as soft and hard practices, with soft practices further subdivided into people focused practices and process focused practices; and hard practices subdivided into tools and techniques, and formal methods.

As evident from these practice classes or domain toolsets, there exists a wide variety of ways to achieve integrated product development. This research captures IPD using two key practices, specifically cross-functional NPD teams and concurrent product development processes. These critical practices are not arbitrarily selected. Instead, they are selected after applying three predefined criteria to the many practices commonly cited in the research literature for achieving integrated product development (e.g., Appendix 1).

The first criterion used to select the practices to capture IPD is *popularity*. The popularity criterion ensures that manufacturing organizations practicing IPD commonly use the practices selected for this study. As data regarding non-adoption will be captured, the popularity of the practice is key to prevent a disproportionate number of practice rejection cases. For example, a virtual design environment using web-based technologies is a recent practice that may help organizations achieve integrated product development (Tay & Ming, 2001). However, although this practice may be important for IPD, its actual diffusion in organizations is expected to be quite low and is therefore rejected.

The second criterion is referred to as *administrative practices*. Ahire and Ravichandran (2001) state that the diffusion of innovations may differ depending upon whether they represent administrative or technological innovations. Technological innovations include the adoption of technology or production processing systems that are new to the organization. Administrative innovations include the adoption of administrative programs, processes, or techniques new to the organization.

Ahire and Ravichandran (2001), referencing studies by Daft (1978) and Damanpour and Gopalakrishnan (1998), emphasize that technological innovations usually begin in the technical core of the organization and diffuse bottom-up. Administrative innovations, on the other hand, typically begin in the administrative core of the organization and follow a top-down diffusion process.

This research study addresses those practices that are diffused in a top-down manner. The reason for selecting administrative practices is that managers of product development, who are the focus of this study, are more likely to play a key role in the initial adoption and diffusion of practices that are diffused top-down versus bottom-up and are therefore in a better position to comment on the diffusion of administrative practices versus technological ones.

The innovation literature also suggests that the factors influencing the diffusion of administrative innovations differ from technological innovations (Ahire & Ravichandran, 2001). Therefore, examining only administrative practices, versus both administrative and technological practices, allows for a more focused research model to be developed. Based on the administrative practice criterion, practices such as IT tools (e.g., internet, common databases, CAD/CAM systems)(Jaing, Harrison, & Cheng, 2002; Jiang & Mo, 2001; Ozer, 2003) and virtual co-location (Martinez, Fouletier, Park & Favrel, 2001; May, Carter, & Joyner, 2000; McDonough III, Kahn, & Barczak, 2001), albeit important for successful NPD, are omitted.

The final criterion is referred to as *theoretical importance*. Theoretical importance implies that the practices must capture the essence of integrated product development. As stated in Chapter One, IPD is comprised of two key components; overlap of NPD activities and interaction between the functional disciplines performing these activities. Various practices may enable this to occur. Based on this final criterion, the practices selected to capture IPD are cross-functional NPD teams, to capture interaction, and concurrent product development processes, to capture overlapping activities. The remaining practices such as relationships with key suppliers and design-for-manufacture are eliminated as cross-functional NPD teams and concurrent product development processes capture in a much broader sense the overall goals of these practices.

2.2.1 Cross-Functional NPD Teams

Cross-functional NPD teams are an integral part of IPD as they represent an effective means of achieving organizational integration (Starbek & Grum, 2003; Swink, Sandvig, & Mabert, 1996). It is therefore not surprising that a cross-functional NPD team is one of the most widely cited practices for achieving integrated product development. A cross-functional NPD team is a team comprised of members representing the functional disciplines most involved in the NPD effort, such as design, R&D, engineering, manufacturing, and marketing.

In addition to internal representation, this team may also include representatives from key suppliers and customers. Participation on a cross-functional NPD team may vary. Possible team structures include a full time dedicated cross-functional NPD team, a mix of part-time and full time team members, members external to the organization, and members who participate on several teams concurrently. Trygg (1993), focusing on 109 Swedish manufacturing organizations, illustrates in Figure 2.1 the extent that various functional disciplines are represented on cross-functional NPD teams.

Figure 2.1

**Representation of Key Functional Disciplines
on Cross-Functional NPD Teams**

Cross-functional NPD teams allow for better decision making by enabling the NPD team to work towards a common goal, instead of following the often conflicting agendas and goals of the individual functional disciplines. Instead of letting each functional area work in isolation from one another and then pass product responsibilities to the next functional area, as traditional stage-gate models of NPD emphasize, cross-functional NPD teams emphasize concurrent decisions. This decentralized decision making considers downstream activities early in the NPD effort and thus helps to prevent costly mistakes in the latter stages of the NPD effort (Henke, Krachenberg, & Lyons, 1993, Trygg, 1993). McDonough III (2000) found that the common reasons for implementing cross-functional NPD teams are to improve speed to market, product quality, customer satisfaction, and cross-functional integration.

Swink et al. (1996) in case studies involving the Boeing Company, Cummins Engine Company, Red Spot Paint and Varnish Company, Texas Instruments, and Thomson Consumer Electronics highlight that cross-functional NPD teams can take many forms, including program management (e.g., provide management oversight and planning, approve large resource allocations, and control the product's budget), technical (e.g., provide technical oversight, approve key design decisions, maintain consistency among design elements), design-build (e.g., address a particular product component), integration (i.e., integrate major product sub-systems), and task force (i.e., address a specific problem, evaluate a design tradeoff, investigate an emerging technology) teams.

One of the advantages of cross-functional NPD teams is that members traditionally from the latter stages of the NPD process become actively involved in early downstream activities. Much research has occurred on the advantages of input from downstream players, such as manufacturing, suppliers, and customers. Gerwin (1993) highlights the advantages and disadvantages of manufacturing input during the front-end development activities.

The advantages of early manufacturing input include: i) as much of the manufacturing cost and quality of a new product is determined by the end of the product concept stage, debate over new technologies and new product concepts should occur during the early front end activities and not after the design of the new product is committed, ii) manufacturing can offer ideas about features needed in the next generation as a result of its downstream experience with the current generation of product, iii) as manufacturing

benefits from direct customer feedback, the product is more likely to resemble what the customer wants, iv) other functional disciplines involved in the development effort must know early what manufacturing can and cannot do, and v) by being involved in the early stages of the NPD process, manufacturing develops a strong commitment to the project (Gerwin, 1993).

Gerwin (1993) also highlights from the product planner's and designer's perspective some of the potential problems of including manufacturing in the early input activities reflecting a combination of misconceptions, "turf wars", and valid concerns that manufacturing must address. These perspectives include: i) "manufacturing people don't have expertise in evaluating market requirements or selecting function and features", ii) "developing a vision for a new product is frustrating work. If too many people are involved at the start, we won't get anywhere", iii) "in the early stages of a project, manufacturing people ask the wrong questions. Their queries are too detail oriented", iv) "manufacturing doesn't devote enough time to taking part; and, by changing its representative, it holds up progress", and v) "manufacturing people have nothing to bring to the table; they can't make a contribution beyond those made by product planners and designers". (p. 127)

Early customer and supplier input may also present some advantages to the NPD effort. Early customer input allows the NPD team to clearly define the needs of the customer, increasing the chances of the product being accepted in the marketplace. Many organizations are realizing the importance of supplier input, and have undertaken efforts

to reduce their supplier base and work more closely with remaining suppliers. The advantages of early supplier involvement in NPD activities include supplier-designed parts which best fit the end product, supplier-developed new technology for the product, end products designed to take advantage of the supplier's technology, supplier-invested capital in the project, and supplier commitment to the new product (Fleischer & Liker, 1997).

It appears that organizations are responding to the many praises of cross-functional NPD teams in developing new products. Trygg (1993), in a survey of 109 Swedish machinery and metalworking organizations, found that over 80% of these organizations used cross-functional NPD teams in their development efforts. Griffin (1997) highlights a 1994 study of 193 organizations by Mercer Management Consultant, Inc., which found that cross-functional NPD are used in 78% of high performing (i.e., top 1/3 in combined innovativeness, success rate, cycle time, and revenue contribution) and 66% of lower-performing organizations. McDonough III (2000), surveying 112 Product Development and Management Association (PDMA) members, found that 97% of the organizations surveyed have used cross-functional NPD teams and that cross-functional NPD teams are always used in 33% of these organizations.

Griffin (1997), in a PDMA sponsored study of NPD best practices spanning multiple industries and products, highlights that over 84% of all new-to-the-world, new-to-the-firm, and major revisions NPD projects use cross-functional NPD teams, an increase from 76% based on results from a similar PDMA study conducted in the early 1990s.

For less innovating projects, such as incremental improvement, repositioning, and cost reduction projects, Griffin (1997) found that cross-functional NPD teams are used only 45% of the time. Comparing the *best organizations*² to the remaining ones, Griffin (1997) concludes that best organizations use cross functional NPD teams in the majority of their NPD, regardless of the level of innovativeness. Figure 2.2 highlights the usage of cross-functional NPD teams on different types of NPD projects.

Figure 2.2

Cross-Functional Teams in NPD

Although there are many advantages of cross-functional NPD teams, their effectiveness in organizations can be hampered by many factors. Problems preventing cross-functional NPD teams from being effective, or fully utilized, in organizations include ineffective team management (Henke et al., 1993), lack of team autonomy (Gerwin & Moffat, 1997),

² *Best organizations* are those who are i.) either the most successful based on a set of performance criteria or in the top third of their industry, and ii.) above the mean on the relative success and market-financial success for the entire sample of 383 organizations. Based on these criteria, the *best organizations* represent 85 companies or 22.2% of the sample.

overuse (Henke et al., 1993), lack of cooperation among individual members of the team (Pinto, Pinto, & Prescott, 1993), physical separation of team members, and lack of cross-training between manufacturing and engineering (Hauck, Bansal, & Hauck, 1997).

A variety of studies have examined the relationship between cross-functional NPD teams and NPD performance. Ettlie (1993), in a study involving 126 projects, found that cross-functional NPD teams positively influences NPD success, measured in terms of meeting technical, cost, and time goals. Ettlie (1995), in a later study involving 57 middle and senior product and engineering managers representing 43 firms or divisions, however, found that the integration of functions during the development process is positively associated with commercial success, measured in terms of sales per employee, but that such functional integration is not associated with cycle time reduction. Moffat (1998), examining 53 projects from 14 companies in the telecommunications, computer, automobile, aircraft engines, and manufacturing process equipment sectors, found an indirect direct association between cross-functional NPD teams and project task performance (i.e., success in meeting company development project goals). Moffat (1998) concludes that this practice improves team effectiveness which, in turn, influences NPD performance.

Droge, Jayaram, and Vickery (2000), in a study of 57 automotive parts and sub assembly suppliers, found that cross-functional NPD teams is positively associated with the ability to minimize new product development time. McDonough III (2000), in a study of 112 PDMA members, found cross-functional NPD teams to be positively associated with

project performance, measured by the extent that new products were brought to market quicker, budgets for developing new products were met, the quality of the products was high, and members of the team were satisfied.

Gerwin and Barrowman (2002), in a meta-analysis of the research on IPD characteristics and NPD performance, found that cross-functional NPD teams reduce development time but not goal failure. Sánchez and Pérez (2003), in a survey of 60 Spanish automobile part suppliers, found a positive significant relationship between cross-functional teams and development time minimization ability.

2.2.2 Concurrent Product Development Processes

Concurrent product development processes involve the execution of certain NPD activities, such as the design of a product and its manufacturing process, concurrently. Swink et al. (1996), examining five large and complex NPD projects, identify three ways in which concurrent processes can occur on development projects, specifically project phase (i.e., concurrently developing marketing concepts, product designs, manufacturing processes, and product support structures), design (i.e., overlapping design disciplines such as system, software, electrical and mechanical engineering so that system level and component level designs are produced concurrently) and product (i.e., overlapping separate, but related, new products requiring coordination between NPD programs) concurrency.

Although many researchers praise the benefits of overlapping NPD activities, Terwiesch and Loch (1999) highlight two major gaps in the research examining this practice. First, the research has not adequately addressed the impact of contextual variables on the effectiveness of concurrent product development activities. Second, in spite of the conceptual literature praising the benefits of concurrent product development processes, only a few industry-specific studies could find a significant product development acceleration effect. Examples include Moffat (1998) who found a direct association between concurrent product development processes and project task performance, Terwiesch and Loch (1999) who, examining 140 development projects from the global electronic industries, found overlap to be a significant accelerator of development time, and Swink (2000) who, in a study of 136 US manufacturing firms, found overlap of development activities to be negatively associated with time goals and time increase.

2.3 Factors Influencing the Diffusion of IPD

Various researchers have emphasized the importance of examining the extent of diffusion of integrated product development (e.g., Gerwin, 2002; Gerwin & Barrowman, 2002; Rusinko, 1999). Yet, a review of the IPD literature fails to identify studies that empirically address this critical research area. Expanding the scope of the literature search, only a handful of research studies have examined the factors that influence the diffusion of NPD practices. These studies, however, suffer the limitation of either not thoroughly examining the extent of diffusion or examining diffusion as a dichotomous (e.g., adopt-reject) variable.

However, given this limitation, as those practices used to achieve IPD also comprise part of the broader set of NPD practices, studies examining the diffusion of NPD practices do provide a relevant starting point for determining possible organizational contextual factors that may influence the diffusion of integrated product development. In addition to the NPD literature, research from the innovation literature must also be examined for possible factors; as IPD can be considered a form of organizational innovation and the extent of diffusion is addressed by this literature body.

There are many factors that may influence the diffusion of an innovation. Rogers (1983) suggests that innovation attributes, characteristics of the adopter, social network to which the adopter belongs, environmental characteristics, process by which the innovation is communicated, and characteristics of those who are promoting an innovation all influence the diffusion of innovations.

Tornatzky and Fleischer (1990) identify various factors that may influence the diffusion of innovations, including the nature of the technology, characteristics of the user, characteristics of the deplorer, boundaries within and between deplorers and users, and characteristics of communication and transaction mechanisms. Rothwell (1992) identifies various organizational contextual factors required for sustained innovation to occur in organizations. These factors are top management commitment to, and visible support for, innovation, a long term strategy in which innovation plays a key role, long term commitment to major projects, corporate flexibility, and top management acceptance of risk.

Frambach and Schillewaert (2002) synthesize the research literature on the diffusion of innovations to develop a multi-level conceptual framework that examines the adoption and continual usage of innovations in organizations. The first layer of the framework addresses the factors influencing the organizational decision to adopt and continually use an innovation. These factors include supplier marketing efforts (i.e., targeting, communication, risk reduction), social network (i.e., interconnectiveness/network participation), perceived innovation characteristics (i.e., relative advantage, compatibility, complexity, trialability, observability, uncertainty), and adopter characteristics (i.e., size, structure, organization innovativeness/strategic posture).

The second layer of Frambach and Schillewaert's (2002) framework addresses the factors influencing individual acceptance of innovations by organizational members. These factors include organizational facilitators/internal marketing (i.e., training, social persuasion, organization support), personal characteristics (i.e., demographics, tenure, product experience, personal values), social usage (i.e., network externalities, peer usage), personal innovativeness (i.e., tendency of a person to accept an innovation independently of the communicated experience of others), and attitudes towards innovation (i.e., beliefs, affects).

Mahajan and Wind (1992) address NPD practice diffusion by examining the formal methods used in the NPD process, reasons for using the formal methods selected, and what specific improvements to these methods are needed to increase diffusion levels. Mahajan and Wind (1992) found the common formal methods used on NPD projects

include focus groups, limited rollout, concept tests, attribute/usage studies, and conjoint analysis. The main reasons for diffusing these formal methods are to improve the success rate of the new product and to identify problems with the product and alternative marketing strategies.

Mahajan and Wind (1992) identify recommendations to increase the diffusion and quality of IPD formal methods based on a survey of 69 Fortune 500 organizations. Recommendations cited for increasing the usage of formal methods on NPD projects include more quantitative approaches, reduction in the time to use the practice, better top management support, the addition to, or improvement of, the forecasting capabilities of some of the methods, better training on the method, customized for specific industries, simplification of the method, more involvement from the customer, more involvement from field sales personnel, better integration across functions, and online information.

Nijssen and Frambach (2000), studying 62 Dutch industrial organizations, found i) senior management involvement with the NPD process has a positive effect on the level of diffusion of NPD tools and techniques, ii) the number of stages within the NPD process has a positive effect on the level of diffusion of NPD tools and techniques, iii) the number of departments involved in the company's NPD has a positive effect on the level of diffusion of NPD tools and techniques, iv) the level of communication between departments has a positive effect on the level of diffusion of NPD tools and techniques, v) an NPD Strategy focusing more on turning out many new products has a positive

effect on the level of diffusion of NPD tools and techniques, and vi) former NPD tools and techniques users are more likely to deploy new NPD tools and techniques.

Studies such as Nijssen and Frambach (2000) and Frambach and Schillewaert (2002) emphasize that there are many different factors influencing the diffusion of innovations in organizations. As IPD can be considered a form of organizational innovation, it is expected that many of these same factors will also impact the diffusion of IPD in Canadian and American manufacturers.

To provide support for their conceptual framework, Frambach and Schillewaert (2002) generate detail tables of recent research that has examined various organizational and individual factors that influence the diffusion of innovations in organizations. Using these tables as a starting point and incorporating additional studies from the innovation diffusion and NPD literature, Appendix 2 highlights various factors that may influence the diffusion of IPD by Canadian and American manufacturers.

2.4 Measures of NPD Performance

There are many different measurements researchers use to assess NPD performance. For example, Ettlie (1995) measures NPD performance by sales per employee and reduced development cycles. Ayers, Dahlstrom, and Skinner (1997) measure project success by the extent to which a project meets its commercial goals. Moffat (1998) measures project task performance in terms of timeliness of delivery, product quality, design iterations / engineering change order reduction, and customer satisfaction. Rusinko (1999) measures NPD effectiveness in terms of decreased cost and lead time and increased quality and

performance. Susman and Ray (1999) measure project outcomes in terms of performance, schedule, and cost. Gerwin and Barrowman (2002) suggest that NPD project performance can be directly measured using development time, development cost, product quality, product cost, and overall project performance.

Duffy and Salvendy (1999), highlight the need for both subjective and objective measurements of NPD performance. Objective measurements are based on performance data from the organization and may include, for example, percentage reduction in cycle time or number of engineering changes; while subjective measurements are based on managerial perceptions of the effectiveness of IPD in improving performance. Although various researchers argue that many objective measurements (i.e., based on actual performance data) do not accurately reflect NPD success, three objective measures commonly viewed to reflect NPD performance are time to market reduction, reduction in the cost of production, and engineering change request reduction (Duffy & Salvendy, 1999).

Time to market reduction is the time reduction, stated in months or as a percentage, to develop new products. Reductions in production costs such as labour, cost of manufacturing technologies, and assembly are also used to measure NPD performance, but measurements based on cost savings should not be the sole indicators of NPD performance (Duffy & Salvendy, 1999). Due to the variations in the team size, company size, and products being developed, the actual dollar savings is of limited utility. Instead,

researchers suggest that the percentage of production cost reduction is a more meaningful measure of performance.

One of the advantages of IPD is a reduction in the number of engineering changes in downstream NPD activities. For companies that develop a wide variety of products of different size and complexity, measuring the number of change requests only provides a small picture of the improvement in engineering changes. In addition to this measurement, researchers also suggest that how much earlier, represented as a percentage, engineering change requests are received is also an effective indicator of engineering change performance. This is considered a relevant measurement as the earlier engineering changes are identified and addressed, the lower the amount of expensive and time consuming changes required in the latter stages of the NPD process.

In addition to obtaining raw numbers or percentages, managerial perceptions (i.e., subjective measurements) of the effectiveness of IPD is also cited as an effective means to assess NPD performance (Duffy & Salvendy, 1999). Subjective measurements are used to obtain managers' high level or general viewpoints of IPD performance and may be captured, for example, by interviews or by using a likert scale with "extremely ineffective" to "extremely effective" as anchors.

Duffy and Salvendy (1999) classify subjective measurements as profitability, competitiveness and organizational maintenance. Integrated product development profitability is captured by measuring managerial perceptions as to the effectiveness of IPD in reducing the cost of production, engineering changes, and increasing return on investment. Competitiveness is measured by capturing managerial perceptions of the effectiveness of IPD in reducing time to market and increasing quality and customer satisfaction. Organizational maintenance is measured by capturing managerial views as to the effectiveness of IPD in increasing the level of group productivity, intergroup / interdepartmental communication, and employee satisfaction.

One of the most extensive listings and reviews of NPD performance measurements is by Griffin and Page (1993). Griffin and Page (1993), reviewing 77 articles covering 61 different research projects, identify 46 different measurements used to assess NPD success. In addition, Griffin and Page (1993), in a survey of 50 NPD practitioners, found that 34 NPD measurements are commonly used and 45 NPD measurements are commonly desired by organizations. Combining these three sources (i.e., used by researchers, used by organizations, desired by organizations), Griffin and Page (1993) generate a list of 75 measurements of NPD performance, as listed in Appendix 3. Of this list of 75 measurements, 16 practices span all three sources. Those practices commonly used by researchers and/or used and desired by organizations, as identified by Griffin and Page (1993), are listed in Table 2.1.

Table 2.1

**NPD Performance Measures
Commonly Used and Desired**

Category	Measures of NPD Performance
Customer Acceptance	Customer acceptance, customer satisfaction level, met revenue goals, revenue growth.
Financial	Break-even time, attains margin goals, attains profitability goals, internal rate of return, return on investment.
Product Level	Cost of developing the product, launched on time, technical performance of the product, performance to specifications, met quality guidelines, speed to market.
Firm Based	Percentage of sales provided by products less than five years old.

Barclay and Dann (2000) combine the measurements used by Loch *et. al*, Lynch and Cross, and McGrath and Romeri to categorize NPD performance measurements into program-based (e.g., targets for cost, time, quality, specifications), company-based (e.g., profit, sales volume, market share), and customer-based (e.g., satisfaction, returns). The measurements Barclay and Dann (2000) identify as important for evaluating successful product development are similar to those of Griffin and Page (1993) and include: market share (%), market position, return on investment, customer satisfaction, break-even time, profit margin, sales target, product performance vs. specification, quality standards, launched on time, within budget, and team satisfaction

Many researchers suggest that IPD does not lead to high performance along all NPD performance measurement indicators. Swink (2000), for example, suggests that IPD positively influences product performance, meeting customer requirements, and manufacturability; but does not lead to large market or financial returns. The main reasons cited for this lack of “across-the-board” improvements in performance is that IPD

is most effective in contexts of high uncertainty and that the benefits of IPD does not span all aspects of NPD effectiveness.

As evident from the latter part of Section 2.2.1 there appears to be no unanimous empirical consensus regarding the impact of certain IPD practices on NPD performance. Problems with the current research that have lead to such inconsistent findings include inappropriate unit of analysis and no control for contributions from other practices or exogenous variables (Moffat, 1998). One of the most extensive attempts at examining the research regarding the relationship between IPD practices and NPD performance and determining why the results are so inconsistent is by Moffat (1998).

Moffat (1998) derives three competing models researchers use to describe the relationship between IPD and NPD performance. The “*Bag of Tricks*” model suggests that each practice or domain toolset used to achieve IPD makes a direct positive contribution to NPD performance. The “*Seamless Model*” adopts the whole is greater than the sum of the parts mentality as described by Moffat (1998):

The different dimensions of integration have a reciprocal impact on each other which significantly improves project performance ... The ‘whole’ integration effect of the [IPD] approach is dramatically greater than the ‘sum’ of the independent contributions of each individual tools and methods, because of this synergy. (p. 61)

The final model, “*Team Effectiveness*”, suggests that some toolsets (i.e., integrated IS tools, manufacturability tools, process standardization methods, and customer input methods) will directly improve NPD performance, while other IPD toolsets (i.e., organizational integrative and simultaneity methods) will indirectly improve NPD performance by directly improving team effectiveness.

Data analysis of 53 NPD projects, however, found no support for the first two models (i.e., *Bag of Tricks*, *Seamless Web*) and only partial support for the third (i.e., *Team Effectiveness*). Moffat (1998) derives a new model outlining the relationship between IPD and project performance, labeled the *Multi-path Model*. This model suggests that organizational integration and manufacturability tools both positively influence simultaneity methods, which in turn, positively influences project performance. Process standardization methods positively influence team effectiveness, while manufacturability tools negatively influence such effectiveness. This team effectiveness, in turn, positively influences project performance.

The lack of consensus regarding the NPD performance of IPD practices emphasizes the need to identify new variables that may significantly moderate the relationship between these two constructs. Considering both this need and the recommendations that studies of IPD must consider the extent of diffusion, this research examines a new variable to be considered in future studies of IPD and NPD performance, specifically the extent of IPD diffusion.

2.5 Conclusion

Integrated product development aids in successful NPD by shortening the NPD process and preventing costly mistakes resulting from misunderstanding and conflict between various functional disciplines (Rusinko, 1999). The benefits of IPD are widely cited in the research literature, including significant reductions in NPD cycle time, product life-cycle costs, and engineering changes.

There are many different practices that an organization can select to achieve integrated product development. Two key practices commonly used to achieve IPD include cross-functional NPD teams and concurrent product development processes. These practices are used to align functional disciplines so they can work toward a common goal (Liker et al., 1999), promote the collective interest of the NPD team and not of the various functional disciplines, and reduce misunderstanding and conflict due to goal and reward differences (Rusimko, 1999).

Although much conceptual research has praised the benefits of these practices, the empirical research outlining the direct impact of these practices to NPD performance is either significantly lacking, as in the case of concurrent product development processes, or has produced conflicting results, as in the case of cross-functional NPD teams. The lack of conclusive results suggests the presence of factors moderating the relationship between the practices used to achieve IPD and NPD performance.

This research introduces a new variable to be considered in future studies examining the relationship between IPD and NPD performance, specifically the extent of IPD diffusion. Although, the need to study the extent of IPD diffusion has been made clear in the innovation literature, IPD researchers have yet to incorporate, in any great effort, issues regarding the extent of IPD diffusion into their work.

Based on reviews of the innovation diffusion and NPD literature, there are many potential factors influencing the diffusion of IPD within organizations. This research examines a subset of these factors, specifically those internal to the organization, yet external to any one NPD project team. The task of selecting these factors and discussing their proposed relationship to the extent of IPD diffusion occurs in Chapter Three.

CHAPTER III

RESEARCH MODEL

3.1 Introduction

This research examines IPD diffusion within Canadian and American manufacturing organizations. To accomplish this task, two separate, but related, issues are explored. First, this research examines those factors promoting or inhibiting the extent of diffusion of IPD within organizations. As there may be many different factors influencing the diffusion of IPD, only those factors internal to the organization, yet external to any individual NPD project or team are examined. Given the large number of practices that can be used to capture IPD and their varying attributes, IPD is captured by examining two key practices, specifically cross-functional NPD teams and concurrent product development processes.

Second, this research examines how IPD performance changes as the diffusion of IPD changes. Integrated product development performance is captured by communication quality (i.e., how well IPD improves communication and integration of the functional disciplines involved in developing new products) and NPD performance (e.g., market share, ROI). Combining these issues, this research examines the determinants and performance consequences of IPD diffusion. The research question is therefore stated as follows:

Research Question

- What are the determinants and performance consequences of IPD diffusion within Canadian and American manufacturing organizations?

This research question will be addressed via the following investigative questions:

Investigative Questions

- What organizational contextual factors influence the extent of diffusion of IPD within Canadian and American manufacturing organizations?
- How does communication quality change with the level of diffusion of IPD within Canadian and American manufacturing organizations?
- How does NPD performance change with the level of diffusion of IPD within Canadian and American manufacturing organizations?

3.2 A-Priori Model of IPD Diffusion

This research proposes that the extent of IPD diffusion will be significantly influenced by the actual and required integration between the functional disciplines involved in new product development. The constructs selected for this study either: i) create a coordination gap or ii) facilitate unity of effort between the functional disciplines involved in developing new products. These organizational contextual factors include various characteristics of the IPD practices that may hamper its diffusion and support for the IPD practices in the organization. In addition to these direct determinants, this research proposes that other factors will indirectly influence IPD diffusion by directly influencing support for IPD practices in the organization. These indirect determinants include the complexity of the organization's NPD activities, the climate of the organization, and the organization's NPD strategy.

The extent of IPD diffusion is captured by the percentage of NPD projects undertaken by an organization during the past two years that used IPD practices. As an organization may use multiple practices to achieve IPD and these practices may be at different levels of diffusion, this research will examine cross-functional NPD teams (CFT) and concurrent product development processes (CDP) as separate constructs. In other words, cross-functional NPD teams and concurrent product development processes are examined as separate dimensions of IPD, instead of simply using the arithmetic mean of these two practices to capture IPD as a uni-dimensional construct. As a result, two hypotheses (i.e., one for each of cross-functional NPD teams and concurrent product development processes) are needed for each relationship tested in the research model.

As previously stated, the second and third objectives of this research are to determine how the extent of IPD diffusion influences IPD performance. This research captures IPD performance by examining how communication quality and NPD performance changes with the diffusion of Integrated Product Development.

New product development performance captures how the current use of IPD impacts the performance of the organization's NPD activities and includes measures such as development time, development cost, ROI, and market share. Communication quality measures how well a practice improves the communication and coordination between the various disciplines involved in developing new products in the organization. Referring back to the team-based rewards example, although this practice is inexpensive and easy to implement, it is expected that it will not do as good of a job of integrating the various

functional disciplines when compared to the more expensive and challenging practice of cross-functional NPD teams, and is therefore of lower quality. An a-priori research model outlining the proposed relationship between the determinants of IPD diffusion, extent of IPD diffusion, and performance consequences of IPD diffusion is illustrated in Figure 3.1.

Figure 3.1

A-Priori Model of IPD Determinants and Consequences

Gerwin and Barrowman (2002) make a number of recommendations for future research studies that explore integrated product development. The major recommendations include using more than simply development time to capture NPD performance, examining the extent of diffusion of IPD, and examining the interaction between various IPD practices.

This research model addresses the two former recommendations. A wide number of performance measurements are used in the research model. These measurements include financial measurements, such as return-on-investment and profit margin, development measurements, such as reduction in engineering changes and performance to specifications, and communication quality measurements, such as the frequency and openness of communication between the functional disciplines involved in new product development. The focus of this model is the extent of IPD diffusion, captured by the percentage of NPD projects undertaken in the past two years that used integrated project development, thus addressing the second recommendation.

The third recommendation cannot be directly incorporated into the research model. To determine an interaction effect, the scores for cross-functional NPD team diffusion and concurrent product development process diffusion must be multiplied together to generate a new interaction variable. As the cross-functional NPD team and concurrent product development process diffusion variables already comprise the research model, this interaction variable cannot be included due to concerns of multicollinearity. This research will instead examine the influence of the interaction variable on NPD performance and communication quality separately from the research model.

3.2.1 Direct Determinants of IPD Diffusion

This research examines various organizational level factors believed to influence IPD diffusion. These factors are chosen after reviewing the NPD literature and identifying those factors most likely to create the need for IPD, facilitate its diffusion, or hamper its diffusion even though a need for IPD exists. This research proposes that the two major

organizational-level determinants of IPD diffusion are practice diffusion difficulty and support for IPD at the various levels in the organization.

Practice diffusion difficulty captures the impact that the characteristics of a specific IPD practice will have on its diffusion. Practice diffusion difficulty is captured by the cost, complexity, risk, and relative advantage of using a specific IPD practice. The innovation diffusion literature suggests that the attributes of an innovation, or technology, will influence its diffusion. Meyers and Goes (1988), for example, found medical innovations that are highly observable, carried low risks, and required relatively little skill (i.e., all attributes of the innovation) are more readily diffused versus other medical innovations. Similarly, Wolfe (1994) suggests that rates and patterns of diffusion are influenced by the attributes of the innovation.

It is expected that the attributes of an IPD practice will influence its diffusion. For example, it is expected that a practice that is inexpensive and easy to use, such as team-based rewards in the form of a completion dinner, will be used on more NPD projects; versus the more expensive and complex practice of a cross-functional NPD team, which may be limited to only the most critical NPD projects. The first set of hypotheses for this research is stated as follows:

- **H_{1A}:** Cross-functional NPD team (CFT) diffusion difficulty will negatively influence the extent of diffusion of cross-functional NPD teams when developing new products.
- **H_{1B}:** Concurrent product development process (CDP) diffusion difficulty will negatively influence the extent of diffusion of concurrent product development processes when developing new products.

One of the more widely cited attributes of an innovation is complexity. For this research, complexity is defined as the extent to which a practice is perceived as relatively difficult to understand and use. Rogers (1983) suggests that the complexity of an innovation is negatively related with its rate of diffusion. Meyer and Goes (1988) found that the skill required to use a medical innovation is negatively associated with its deployment. Tornatzky and Klein (1982), examining thirteen studies of complexity, found that all but one showed a significant negative relationship between innovation complexity and adoption. This research, following Rogers (1983), Meyers and Goes (1988), and Tornatzky and Klein (1982), expects that the complexity of the practices selected to achieve IPD will negatively influence their extent of diffusion.

In addition to complexity, practice cost is also a widely cited innovation attribute. Although, the conceptual innovation literature suggests that the cost of an innovation negatively influences its diffusion, only limited empirical support exists (Tornatzky & Klein, 1982). One of the major disadvantages cited for IPD formal methods, such as Quality Function Deployment and Design for Manufacture, and a reason for low consistent usage is the cost of using such methods (Trygg, 1993). The cost of constantly using expensive practices such as cross-functional NPD teams and concurrent product development processes may be so great that their usage may be limited to critical development projects. This research therefore expects that the ongoing cost of an IPD practice will negatively influence its diffusion.

Risk is operationalized as the level of risk involved in using the practices selected to achieve integrated product development. The innovation literature highlights that the risk of using an innovation negatively influences its diffusion. For example, Meyer and Goes (1988) found risk negatively influences the diffusion of medical innovations. Similarly, it is expected that the risk of using an IPD will negatively influence its diffusion.

Relative advantage is the degree to which an innovation is perceived as being better than those it supercedes. Rogers (1983) highlights that relative advantage is one of the best predictors of innovation adoption rates:

When individuals pass through the innovation-decision process, they are motivated to seek information in order to decrease uncertainty about the relative advantage of an innovation. Potential adopters want to know the degree to which the new idea is better than an existing practice. So relative advantage is often the content of the network messages about an innovation. The exchange of such innovation-evaluation information lies at the heart of the diffusion process. (p. 217)

Relative advantage can be measured in many different ways, including economic profitability, social benefits, time saved, or hazards removed (Tornatzky & Klein, 1982). As highlighted in Chapter Two, there are many benefits of integrated product development. This research will capture managers' perceptions of the major benefits of IPD and how these benefits influence the extent of diffusion of IPD in their organization. It is expected that the relative advantage of a practice will positively influence its diffusion. As a result, relative advantage is reverse coded for this research. For example, a score of nine for this question will become one. Likewise, a score of one will become nine. Organizational member support measures the extent that various members of the organization support the ongoing use of IPD in the organization. It is expected that

organizational support will positively influence the extent of IPD diffusion, as IPD practices will be easier to implement when, for example, the use of IPD is supported by senior members of the organization. In addition, due to the similarities of the IPD practices selected for this study, it is expected that high levels of cross-functional NPD team support will be associated with high levels of concurrent product development process support, and vice versa. The relationship between organizational member support and the extent of IPD diffusion is stated as follows:

- **H_{2A}:** Organizational member support for cross-functional NPD teams will positively influence the extent of diffusion of cross-functional NPD teams when developing new products.
- **H_{2B}:** Organizational member support for concurrent product development processes will positively influence the extent of diffusion of concurrent product development processes when developing new products.
- **H_{2C}:** The level of support for cross-functional NPD teams will be positively associated with the level of support for concurrent product development processes.

Organizational member support is captured by senior management, departmental, and employee support for IPD. The importance of senior management support for successful IPD and NPD is widely acclaimed in the literature. For example, Mahajan and Wind (1992) suggest that senior management support influences NPD tool adoption. Smith and Reinertsen (1998) suggest various ways that senior managers can increase the chances of successful new product development. These activities include, for example, clarifying strategic intent (e.g., how a particular new product is linked to the organizational strategy), initiating the project, overseeing the use of resources (e.g., ensuring that the companies assets are being put to good use), and solidifying agreements between key NPD functions.

Swink (2000) identifies similar advantages, including enabling team members to achieve their development goals by providing vision, direction, enthusiasm, priority, and access to required resources. Nijssen and Frambach (2000) found that senior management involvement in the NPD process has a positive effect on the level of NPD tool diffusion. Similar to Nijssen and Frambach (2000), this study proposes that senior management support for IPD will positively influence its diffusion in organizations.

It is also expected that both department managers and employees must support IPD in order for it to be used to its fullest potential in organizations. The use of cross-functional NPD teams and concurrent product development processes may require extensive changes to the departments involved in developing new products. Such changes may include, for example, extensively changing the process of developing new products (i.e., from a stage gate NPD process to a concurrent development process) and enabling employees from various departments to allocate more, or all, of their time on a specific NPD project (i.e., dedicated NPD teams). It is expected that if department managers support the use of IPD, then such changes may occur quicker and with less resistance. As a result, it is expected that department managerial support for IPD will ease the diffusion of IPD in organizations.

In addition to these departments, IPD may also require extensive changes from the individuals who actually develop new products (e.g., scientists, product engineers, manufacturing engineers, marketing representatives). Such changes may include, for example, reporting relationships (i.e., functional manager versus NPD manager) and

goals (i.e, functional goals versus NPD teams based goals). If the use of IPD, and its resulting changes, is met with large resistance from employees actively involved in developing new products, then it is expected that the diffusion of IPD may be limited until such issues are resolved. As a result, it is expected that employee support for IPD will positively influence its extent of diffusion.

3.2.2 Indirect Determinants of IPD Diffusion

This research proposes that practice diffusion difficulty and IPD support will directly influence the extent of IPD diffusion. In addition, however, one must also consider the presence of other factors that may indirectly influence IPD diffusion by influencing these direct determinants. This research suggests that three factors will indirectly influence the extent of IPD diffusion by directly influencing organizational support for IPD. These indirect determinants are the complexity of the organization's NPD activities, climate of the organization, and the NPD strategy of the organization.

New product development complexity is captured by assessing the major characteristics of the organization NPD activities which contribute to task or technology uncertainty. It is expected that an organization with complex NPD activities will possess higher levels of task uncertainty and will therefore have an increased need for IPD practices. As a result, it is expected that such organizations will have an easier time justifying the use of IPD practices, versus those with NPD activities of low complexity and task uncertainty.

- **H_{3A}:** NPD complexity will positively influence organizational support for cross-functional NPD teams when developing new products.
- **H_{3B}:** NPD complexity will positively influence organizational support for concurrent product development processes when developing new products.

The measurements used to capture NPD complexity represent a modification of the project complexity indicators developed by Barclay and Dann (2000). Barclay and Dann (2000) use various measurements to capture the size and complexity of an individual project, in terms of the time, personnel, and functional disciplines required. These measurements include the number of working person days, number of disciplines involved in NPD projects, number of functions involved in developing the product in the organization, number of design personnel involved in developing products in the organization, and the number of people external to the organization involved in developing new products. In addition to the variables identified by Barclay and Dann (2000), the general size of NPD projects, in terms of financial cost, undertaken by the organization will also be used to capture NPD Complexity.

Rogers highlights that the size of the organization is a “surrogate measure of several dimensions that lead to innovation: total resources, slack resources, technical expertise of employees, organizational structure, and so on” (Nijssen & Frambach, 2000, p. 125). Other measures highlighted by Nijssen and Frambach (2000) include level of education of employees, more formal structure in larger organizations, increased need for new products in larger versus smaller organizations, and that larger organizations “are more likely to employ engineers that have learned about NPD tools and techniques and/or that are in touch with consultants or market research agencies that use them” (p. 125).

The major weakness of considering organization size in research studies is that i) organization size only captures indirect relationships which may not hold, or contradict one another, in many cases, and ii) given the wide number of indirect relationship that exist, organization size may not capture the same thing in different organizations or studies. This research will not directly capture organization size. Various measures of NPD complexity, including for example, the number of disciplines and design personnel involved in developing products, are instead used as proxy measures of organization size.

This research proposes that the climate of the organization will influence support for IPD practices. It is expected that IPD will be more supported in organizations that are innovating in general. Such a climate is defined for this research as an innovative organizational climate. This research proposes that organizations with an innovative climate are likely to be open to new ideas, less resistant to IPD and therefore more likely to support IPD diffusion.

Adapting Wallach's (1983) research, an innovative organizational climate is captured using three dimensions, specifically organizational support, innovativeness, and bureaucracy. Organizational support is an organization incorporating values of harmony, openness, friendship, collaboration and trust (Wallach, 1983). As suggested by Wallach (1983), these organizations are "warm and fuzzy" places to work. Eisenberger, Fasolo, and Davis-Lamastro (1990) found a positive relationship between a supportive organizational climate and organizational innovation in the absence of personal recognition. It is therefore expected that members in an innovative organizational

climate may be more willing to support the use IPD, especially when it means no immediate tangible rewards or recognition. Organizational support is captured by the extent that the organization incorporates values of openness and collaboration.

Organizational innovativeness is the extent that the organization is receptive to change, risk taking, results oriented, and creative. Wallach (1983) describes such organizations as exciting and dynamic, where entrepreneurial and ambitious people can thrive. The innovation literature suggests that organizational innovativeness influences innovation diffusion. For example, Frambach and Schillewaert (2002) highlight that the extent to which an organization is receptive to new ideas will influence its tendency to adopt new NPD practices. Based on the innovation literature, it is expected that organizational innovativeness will positively influence support for IPD in the organization. Organizational innovativeness is captured by the extent that the organization is risk taking and receptive to change.

This research also expects that the organizational structure will influence the extent of IPD diffusion in organizations. The organizational structure can range from decentralized to bureaucratic. A bureaucratic structure places restrictions on information flow and decision-making (Shadur et al., 1999). This may restrict support for IPD diffusion, as IPD emphasizes group decision-making and communication. Bureaucracy is captured as the extent that the respondent's organization is bureaucratic and will be reverse coded for this research. The relationship between an innovative organizational climate and support for IPD is stated as follows:

- **H_{4A}**: An innovative organizational climate will positively influence cross-functional NPD team support.
- **H_{4B}**: An innovative organizational climate will positively influence concurrent product development process support.

It is expected that in an organization where NPD is key to competitive success, there will be a greater need for successful NPD and thus greater support for integrated product development. Nijssen and Frambach (2000) found that an NPD strategy focusing more on developing many new products positively influences the extent of diffusion of NPD practices. If the development of new products forms a large portion of the competitive strategy of the organization, then it is expected that there will be a much larger need for successful NPD, and thus increased support for integrated product development. For example, it is expected that the diffusion of expensive IPD practices, such cross-functional NPD teams and concurrent product development processes, will be greater in such organizations; as the need for these practices can be related directly back to the organizational competitive strategy.

In a broader context, Rothwell (1992) suggests that a long-term corporate strategy where innovation plays a key role is required for the needed technical, marketing, and production synergies for successful new product development. The relationship between the organization's NPD strategy and the extent of IPD diffusion is stated as follows:

- **H_{5A}**: An NPD strategy focused on turning out new products will positively influence the organizational support for cross-functional NPD teams when developing new products.
- **H_{5B}**: An NPD strategy focused on turning out new products will positively influence the organizational support for concurrent product development processes when developing new products.

A two stage approach is used to create a single measure to represent the NPD strategy of the organization. The percentage of NPD projects undertaken by the organization during the past two years that fall into the categories of new-to-the-world (i.e., PERNTW), new-to-the-country (i.e., PERNTC), new-to-the-firm (i.e., PERNTF), major modification to an existing product (i.e., PERMAJ), and incremental innovation (i.e., PERINC) is first calculated. Next, a weight is assigned to each category to create a single measure of NPD strategy, stated as follows:

$$\text{NPD Strategy} = 5 \times \text{PERNTW} + 4 \times \text{PERNTC} + 3 \times \text{PERNTF} + 2 \times \text{PERMAJ} + 1 \times \text{PERINC}$$

3.2.3 Extent of IPD Diffusion

Following the suggestions of Gerwin and Barrowman (2002), this research examines the extent of IPD diffusion, instead of the dichotomous accept/reject variable commonly found in the IPD literature. This research captures IPD diffusion by the percentage of NPD projects undertaken by the organization during the past two years that use cross-functional teams and/or concurrent product development processes. This approach is selected, versus presenting a set of specific diffusion stages (e.g., used all the time, using less than 50% of NPD projects, not used) as it will capture the most detailed information regarding the extent of diffusion and will allow future researchers to easily convert the results of this study to any future diffusion scales. In addition, capturing data using a ratio scale versus an interval one should improve the variance explained by the model (Jackson, 2003).

3.2.4 IPD Performance

Based on the literature review, this research expects that the extent of IPD diffusion will positively influence NPD performance. The next set of hypotheses for this research is stated as follows:

- **H_{6A}**: The extent of cross-functional NPD team diffusion will positively influence the NPD performance of Canadian and American manufacturers.
- **H_{6B}**: The extent of concurrent product development process diffusion will positively influence the NPD performance of Canadian and American manufacturers.

As evident from Chapter Two and Appendix 3, a wide number of measurements of NPD performance exist in the research literature. The measurements selected to capture NPD performance are those used by Barclay and Dann (2000). As outlined in Chapter Two, these measurements include: market share (%), market position, return on investment, customer satisfaction, break-even time, profit margin, sales target, product performance vs. specification, quality standards, launched on time, within budget, and team satisfaction.

These practices are selected as they are commonly used to capture NPD performance (e.g., Barclay & Dann, 2000; Griffin & Page, 1993), are general enough to be answered by the research subjects, and have been formatted and tested by Barclay and Dann (2000) for use on a questionnaire, the research instrument selected for this study. In addition to these measurements, the number of changes in the latter stages of the NPD process will also be captured, as this measurement has been highlighted by various researchers (e.g.,

Duffy & Salvendy, 1999; Moffat, 1998) as a means to measure the performance of IPD in organizations.

Cross-functional NPD teams, regardless of their diffusion in an organization, do not guarantee effective product development (Clark & Fujimoto, 1991). For many organizations, a specific practice may simply not work well at achieving integrated product development. For example, in an organization where NPD is not viewed as important and no clearly defined goals exist for NPD, a cross-functional NPD team may not achieve the integration of functional disciplines as a result of the dual loyalties (i.e., project team and functional discipline) and conflicting goals of team members.

Communication quality is the ability of the practices selected to achieve IPD to actually perform their intended purpose which, based on the definition of IPD, is to improve the communication and integration between the various functional disciplines involved in developing new products. Olson et al. (2001) highlight that researchers rarely agree on what functional integration actually means, with definitions ranging from the simple, such as frequency of interaction, to the multidimensional such as collaborative behaviours and attitudes where departments work together, have mutual understanding, common vision, shared resources, and achieve collective goals. This research will capture communication quality as a multi-dimensional construct.

Hoegl and Gemuenden (2001), after interviewing 575 team members, team leaders, and managers representing 145 software development teams, found that teamwork quality can be captured through six manifest variables, labeled: communication, coordination, balance of member contribution, mutual support, effort, and cohesion; as defined in Table 3.1.

Table 3.1
Teamwork Quality Construct

Manifest Variable	Definition
Communication	Is there sufficiently frequent, informal, direct, and open communication?
Coordination	Are individual efforts well structured and synchronized within the team?
Balance of Member Contributions	Are all team members able to bring in their expertise to their fullest potential?
Mutual Support	Do team members help and support each other in carrying out their tasks?
Effort	Do team members exert all efforts to the team's tasks?
Cohesion	Are team members motivated to maintain the team? Is there team spirit?

Hoegl and Gemuenden (2001) examine teamwork quality using the team as the unit of analysis. For this research, however, the unit of analysis is the organization and the specific variables under examination are organizational contextual in nature. The teamwork quality measurements developed by Hoegl and Gemuenden (2001) are therefore used as a starting point, with modifications being made to these measurements, where necessary, to better reflect the essence of integrated product development. Communication quality is therefore captured by measuring the extent that IPD has improved the integration (i.e., the extent that functional disciplines involved in NPD work together and towards the same common goals) and communication (i.e., how well the various functional disciplines communicate with one another when developing new products) between the functional disciplines involved in NPD activities.

Communication quality is captured by measuring the frequency of communication between the functional disciplines involved in NPD, extent of open communication between the functional disciplines involved in NPD, the extent that the NPD goals are understood by the functional disciplines involved in NPD, the coordination between the functional disciplines involved in NPD, amount the functional disciplines support one another when developing new products, the ability of the functional disciplines to reach consensus regarding important NPD issues, the extent by which NPD is viewed as a priority by the functional disciplines involved in NPD, and the extent that functional disciplines are involved in NPD activities.

This research proposes that the extent of IPD diffusion will positively influence the communication quality between the departments involved in developing new products. The relationship between the extent of IPD diffusion and communication quality is stated as follows:

- **H_{7A}:** The extent of cross-functional NPD team diffusion will positively influence the quality of communication between the functional disciplines involved in new product development.
- **H_{7B}:** The extent of concurrent product development process diffusion will positively influence the quality of communication between the functional disciplines involved in new product development.

Communication quality is focused specifically on the integration and communication between the functional disciplines involved in product development activities. It is concerned with the frequency and quality of communication and interaction between these functional disciplines and the extent that common goals exist and are clearly understood. This differs from an innovative organizational climate. The latter is much

broadier in the sense that i.) it is focused on the organization's resistance to new ideas and innovations in general, and ii.) it focuses on the organization as a whole, and not just a few functional disciplines. In addition, an innovative organizational climate does not address clarity of goals or frequency of communication between specific disciplines, both major components of communication quality.

3.3 Conclusion

This research examines the diffusion of IPD within Canadian and American manufacturing organizations. To accomplish this task, three research issues are considered, specifically: i) those organizational contextual factors promoting or inhibiting the diffusion of IPD in organizations, ii) how NPD performance changes as the diffusion of IPD changes, and iii) how communication quality changes as the diffusion of IPD changes.

To test these relationships, an a-priori research model is developed focusing on organizational contextual determinants of IPD diffusion and not those common to any one project or team. The organizational contextual factors selected for this study either create a coordination gap or facilitates or supports unity of effort between the functional disciplines involved in developing new products. These direct determinants include practice diffusion difficulty and support for the IPD practices in the organization.

In addition to these direct determinants, the research model proposes that other factors will indirectly influence IPD diffusion by directly influencing support for IPD practices. These indirect determinants include the complexity of the organization's NPD activities, the climate of the organization, and the organization's NPD strategy. Finally, the research model proposes that IPD diffusion will positively influence both the NPD performance of the organization and the quality of communication between the functional disciplines involved in new product development.

CHAPTER IV

RESEARCH METHOD

4.1 Sampling Frame

Since this study addresses organizational contextual factors and intra-organizational diffusion, attention must centre on the entire NPD effort of the organization and not individual projects. The unit of analysis is therefore the organization. As a result, this research will not examine individual project teams as is common in the IPD literature. Instead, attention will focus on those individuals who are in the best position to comment on organizational contextual factors and their implications on IPD diffusion, specifically the manager responsible for new product development³.

The sampling frame for this study comprises of managers of product development from Canadian and American manufacturing organizations operating in industries where the use of IPD is likely. The industries selected for this study are represented by North American Industry Classification System (NAICS) Codes 333 (i.e., Machinery Manufacturing), 334 (i.e., Computer and Electronic Product Manufacturing), 335 (i.e., Electrical Equipment, Appliance, and Component Manufacturing), and 336 (i.e., Transportation Equipment Manufacturing) and are defined in detail in Appendix 4. Organizations possessing these NAICS codes have been obtained from two commercial directories, specifically the *Scott's Online Directory* for Canadian manufacturing

³ A variety of official titles may be used to describe such an individual, including Vice President/Director of Product Management, Vice President/Director of Research and Development, Vice President/Director of Product Development, or Vice President/Director of Technology. For this research, the person responsible for managing product development activities is hereafter referred to as simply the Manager of Product Development or NPD Manager.

organizations and the *Manufacturers News, Inc. Directory* for American manufacturing organizations.

4.2 Pilot Study

A pilot study involving 490 US managers of product development was conducted during October and November, 2002. Although most pilot studies are not of this magnitude, a large pilot study sample is desired for a number of reasons. First, due to the newness of various model constructs (e.g., CFT and CDP support, CFT and CDP practice diffusion difficulty) an adequate number of returned questionnaires (i.e., $n \geq 30$) is desired to test the internal consistency of the model constructs prior to conducting a full scale study. Second, a moderate number of returned questionnaires may help to identify common problems with the design of the questionnaire not found in the pretest. Third, as a similar study using mail based questionnaires and commercial databases (i.e., Griffin, 1997) achieved response rates of less than five percent, a large pilot study sample is needed to achieve the first two points.

Each individual manager was mailed a survey kit containing a cover letter, questionnaire, and self-addressed stamped return enveloped. To increase the response rate, the survey kits were addressed to an actual individual in the organization (e.g., “Dear Tracy Holmes”), instead of “Dear Manager of Product Development” or some similar generic title. The survey kit was first sent to individuals possessing the title of Vice President/Director/Manager of Product Development. If that title did not exist in the organization, then the survey kit was sent to individuals with the title of Vice President/Director/Manager of Research and Development.

The purpose of the cover letter is to introduce the research and ask for participation in the study. This letter was written on official Eric Sprott School of Business letterhead to ensure professionalism and provide the respondent with a sense of legitimacy regarding the study. The cover letter begins by introducing the author and the scope of the research. This is followed by a paragraph explaining the general questions that the research study examines. Next, instructions for completing the questionnaire are presented. The letter concludes with a note emphasizing confidentiality of returned questionnaires and anonymity of the respondents. This research cover letter is illustrated in Appendix 5.

The questionnaire comprises of a cover page and four sections and is presented in Appendix 6. Appendix 7 outlines how the questions found on the questionnaire captures the manifest and latent variables outlined in the proposed research model developed in Chapter Three. Section one of the questionnaire captures the general organizational data (e.g., organizational climate, structure, and types of products developed), communication quality, and NPD performance. Section two of the questionnaire captures the extent of diffusion of cross-functional NPD teams and the functional disciplines typically represented on such teams.

Section three focuses on the use of concurrent product development processes in the respondent's organization. This section captures the extent of diffusion of concurrent product development processes and those NPD activities that are overlapped or preformed concurrently. Section four is the open-ended section of the questionnaire. In this section,

the respondent is invited to provide general comments regarding the use/nonuse of IPD in their organization. This is followed by a statement expressing appreciation for completing the survey and the name and contact information (i.e., mailing address, email address, phone number, and fax number) of the author.

Due to financial and time constraints, only one wave of mailing occurred. Of the 490 questionnaires mailed, 65 were returned, for a total response rate after one round of mailing of approximately 13.3%. However, of the 65 returned, six were unusable. The total number of questionnaires used in the pilot study is therefore 59, for a usable response rate of approximately 12%.

4.3 Summary of Questionnaire Modifications

Analyzing the data from the pilot study it is apparent that a number of minor changes to the original questionnaire (i.e., Appendix 6) are required. These changes are discussed in detail in Appendix 8. First, changes are needed to fix survey questions 11 and 15 in Appendix 6. These questions have been modified to ensure that the respondent will go to the appropriate section of the questionnaire upon reading the question. Second, the number of options for selecting the extent of diffusion of cross-functional NPD teams (i.e., survey question 10 in Appendix 6) and concurrent product development processes (i.e., survey question 14 in Appendix 6) has been reduced, as no respondent completed two of the options.

Third, examining the pilot study data it is apparent that placing two “Other (Please Specify):” items for survey question 13 in Appendix 6 is not needed as no respondent completed both items and only one completed one item. Fourth, two new open-ended questions have been added to capture additional reasons influencing the diffusion of IPD and qualitatively support or deconstruct various components of the research model. Fifth, due to the good internal consistency of the model constructs, there are only a few modifications needed to the items that comprise various constructs in the model. Specifically, the benefits of cross-functional NPD teams and concurrent product development processes are removed from Questions 12 and 16 in Appendix 6. The final version of the questionnaire for this research study is presented in Appendix 9.

CHAPTER V

DATA COLLECTION

5.1 Full-Scale Survey

Based on the results of the pilot study, a revised survey kit was developed and mailed to managers of product development from Canadian and American organizations with between 50 – 1000 employees and a North American Industry Classification System (NAICS) Code of 333 (i.e., Machinery Manufacturing), 334 (i.e., Computer and Electronic Product Manufacturing), 335 (i.e., Electrical Equipment, Appliance, and Component Manufacturing), or 336 (i.e., Transportation Equipment Manufacturing). A total of 2010 survey kits were mailed to these individuals during late January and early February, 2003⁴. Each kit contained the identical cover letter as the pilot study survey (i.e., Exhibit 6), the revised questionnaire (i.e., Exhibit 9), and a self-addressed stamped return envelope.

5.2 Questionnaire Response Rate

Since no major changes were made to the pilot study questionnaire, the 57 questionnaires used in the pilot study are also used in the final data analysis. Therefore, of the 2500 managers of product development mailed questionnaires between November 2002 and February 2003, 304 completed questionnaires were returned while 79 were returned undelivered. The overall response rate is therefore 12.6 % calculated as $304 / (2500 - 79)$. However, of these 304 returned questionnaires, 35 are unusable. As a result, the usable number of questionnaires for this study is 269 for a usable response rate of 11.1%, as summarized in Table 5.1.

Table 5.1

Summary of Returned Questionnaires

	Total Number of NPD Managers	Returned Questionnaires	Unusable Questionnaires	Usable Questionnaires
Pilot Study	490	65	8	57
Full-Scale	2010	239	27	212
Total	2500	304	35	269

The reasons for rejecting eight questionnaires from the pilot study are explained in Chapter Three. As with the pilot study, the reasons for rejecting 27 questionnaires from the full-scale survey also varied. For eight of these questionnaires, respondents indicated that NPD activities did not take place in their organization. For example, two such respondents indicated that the customer provides the company with the design specifications for the product they wanted manufactured.

Three questionnaires were rejected because the responding organization's NPD activities took place outside of North America. Seven questionnaires were returned blank with no explanation given as to why it was not completed. Two questionnaires were rejected because they appeared to have been biased. Specifically, the respondent selected the same score for all questions in various sections of the questionnaire. The remaining seven questionnaires were rejected because the respondent left the majority of the questionnaire blank.

⁴ Hereafter referred to as the "full-scale survey".

For an NPD study using mail based questionnaires and commercial databases, a usable response rate of 11.1 % can be considered very good. For example, Griffin (1997) in a study of NPD practices using mail based questionnaires and the American Marketing Association and CorpTech commercial databases achieved usable response rates of 1.3 and 2.6 %, respectively.

Telephone and e-mail correspondence from various non-respondents identified various reasons why individuals did not return the questionnaire. These reasons include non-disclosure policies in the organization, the individual to whom the survey kit was addressed to had left the company, and the organization was not involved in new product development.

Other possible reasons not addressed by non-respondents, but still likely, include lack of time to complete the questionnaire and the use of a commercial database to obtain the names for the sampling frame. Since the names for the sampling frame were taken from commercial databases, it is expected that many respondents are frequently solicited to participate in research studies. Therefore, it is possible that many did not participate in this study as they may have participated in another study some short time ago.

CHAPTER VI

DESCRIPTIVE STATISTICS

6.1 Overview of Responding Organizations

The industries selected in this study are fairly well represented in the dataset. Of the 269 questionnaires returned, 135 are from organizations with a NAICS code of 333 (i.e., Machinery Manufacturing), 71 are from organizations with a code of 334 (i.e., Computer and Electronic Product Manufacturing), 36 are from organizations with a code of 336 (i.e., Transportation Equipment Manufacturing), with the remaining 27 from organizations with a code of 335 (i.e., Electrical Equipment, Appliance, and Component Manufacturing). Of these 269 organizations, 29 are from Canada and 240 are from the United States. As discussed in the next chapter, ANOVA is performed to identify any mean differences in the variables between these four industries. The sizes of the organizations that participated in this research study ranged from 50 to 1000 employees, with the average company size being 218 employees. Due to this wide range, ANOVA will also be performed to identify any mean differences between small (i.e., < 100), medium (i.e., 101 – 500), and large organizations (i.e., > 500).

6.2 Type of Product Development

To gain a better understanding of the nature of the responding organizations' NPD activities, the types of NPD projects undertaken by the organization and the perceived level of risk of these projects are addressed. To determine the type of NPD activities the responding organizations are engaged in, respondents were asked to indicate the number of new-to-the-world, new-to-the-country, new-to-the-firm, major revision to an existing product, and incremental improvement projects undertaken during the past two years, as

presented by Question 5 of the questionnaire (i.e., Appendix 9) and illustrated in Figure 6.1

Figure 6.1

Type of NPD Activities

Please indicate the approximate number of products developed by your organization during the past two years that fall into the following categories:

- _____ **New to the world**
- _____ **New to the country**
- _____ **New to the firm**
- _____ **Major revision to an existing product**
- _____ **Incremental change to an existing product**

Converting the data captured by this question into percentages, the mean percentage of the different types of NPD projects undertaken are listed in Table 6.1.

Table 6.1

Percentage of NPD Activities

	N	Minimum	Maximum	Mean	Std. Deviation
PERNTW	258	.00	1.00	.0791	.13163
PERNTC	258	.00	.50	.0611	.09798
PERNTF	257	.00	1.00	.2333	.21832
PERMRV	258	.00	1.00	.2513	.20323
PERINC	258	.00	1.00	.3760	.26924
Valid N (listwise)	257				

Analyzing the data, the most common type of projects undertaken are incremental innovations, comprising on average 38% of the organization's NPD projects. This is followed by major revision, new-to-the-firm, new-to-the-world, and new-to-the-country type NPD projects, comprising of 25%, 23%, 8%, and 6% of NPD projects undertaken, respectively.

The perceived level of risk of the organization's NPD activities are captured using two open-ended questions on the questionnaire (i.e., Questions 3 and 4 in Appendix 9). These questions are stated as follows:

- Please indicate the approximate percentage of NPD projects undertaken during the past two years that, when they were started, had greater than a 50% chance of failing: _____ %
- Please indicate the approximate percentage of NPD projects undertaken during the past two years that actually did fail: _____ %

Calculating the arithmetic means for the percentage with a failure probability of greater than 50% (i.e., PROFAILP) and those that actually did fail (i.e., PROFAILA) indicates that the organizations under study are engaging in moderately risky NPD activities, with approximately 23% of the projects undertaken having a greater than a 50% chance of failing and 12% actually failing, as illustrated in Table 6.2.

Table 6.2

Level of Risk of NPD Activities

	N	Minimum	Maximum	Mean	Std. Deviation
PROFAILP	266	.00	100.00	23.3008	25.85956
PROFAILA	263	.00	100.00	12.0336	17.80410
Valid N (listwise)	263				

6.3 Cross-Functional NPD Teams

As expected based on the literature review IPD, as captured by cross-functional NPD teams and concurrent product development processes, is used in the majority of the organizations that responded to the questionnaire. Of the 269 responding organizations, cross-functional NPD teams are used in approximately 87% of these companies. Among those organizations using cross-functional NPD teams, it is used on an average of 76% of NPD projects. A wide number of functional disciplines are represented on these NPD teams. Based on performing One-Sample Student's t-test, those functional disciplines typically represented or not represented on the organization's cross-functional NPD teams are presented in Table 6.3.

Table 6.3
One-Sample Student's T-Test

	Test Value = 5					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
CFTRD	14.471	197	.000	2.3232	2.0066	2.6398
CFTDESGN	26.966	212	.000	2.9812	2.7633	3.1992
CFTENG	36.397	221	.000	3.2027	3.0293	3.3761
CFTMANU	19.467	227	.000	2.3026	2.0696	2.5357
CFTMKT	9.449	217	.000	1.4610	1.1563	1.7658
CFTFIN	-2.070	215	.040	-.3565	-.6960	-.0170
CFTSALES	7.827	219	.000	1.1659	.8723	1.4595
CFTPLAN	2.074	175	.040	.3807	.0185	.7429
CFTQUAL	10.304	221	.000	1.6261	1.3151	1.9371
CFTPUR	7.782	225	.000	1.2257	.9153	1.5360
CFTCUST	3.201	219	.002	.5386	.2070	.8703
CFTSUP	.855	219	.394	.1341	-.1752	.4433

Based on the mean difference, the functional disciplines typically represented on cross-functional NPD teams (i.e., large positive mean differences) include Engineering (i.e., CFTENG), Design (i.e., CDTDESGN), R&D (i.e., CFTRD), Manufacturing (i.e., CFTMANU), Quality (i.e., CFTQUAL) and Marketing (i.e., CFTMKT).

Although cross-functional NPD teams are popular in organizations, they are not without their risks. An open-ended question on the questionnaire (Question 13, Appendix 9) was presented to respondents in order to capture such risks. Analyzing Question 13 using QSR NUD*IST (i.e., Appendix 10), the commonly cited risks of using cross-functional NPD teams include the time and cost resources required to make these teams effective, competing agendas among members of cross-functional NPD teams, and competition for resources with the various functional disciplines.

6.4 Concurrent Product Development Processes

The second practice used to capture IPD for this research is concurrent product development processes. This practice is used in approximately 77% of the responding organizations. Compared to the 87% usage of cross-functional NPD teams, concurrent product development processes are not used as frequently as cross-functional NPD teams. Among those organizations using concurrent product development processes, it is used on approximately 73% of the organization's NPD projects. Approximately 70% of the organizations used both cross-functional NPD teams and concurrent product development processes when developing new products, while 24% used both practices 100% of the time when developing new products.

To capture the activities that are commonly overlapped, an open-ended question was presented to respondents (i.e., Question 19, Appendix 9). The complete list of activities overlapped is presented as QSR NUD*IST output in Appendix 11. The commonly cited activities, and as expected based on the literature review in Chapter Two, include design, R&D, and various engineering disciplines. As with cross-functional NPD teams, respondents were also asked to indicate the risks of using concurrent product development processes (i.e., Question 18, Appendix 9). Analyzing these data using QSR NUD*IST (i.e., Appendix 12) the common risks of using concurrent product development processes include increased development costs, increase in rework, and poor communication between functional disciplines.

CHAPTER VII

DATA ANALYSIS

7.1 Tests of Internal Consistency

The research model developed in Chapter Three is tested using path analysis. Before testing the research model, tests of internal consistency are needed. If a latent variable is internally consistent, then it will be treated as uni-dimensional by calculating the arithmetic mean of the manifest variables used to comprise it. If a latent variable is not internally consistent then its manifest variables will each enter into the path analytic model.

The procedure for testing the internal consistency of the latent variables is identical to that performed in the pilot study. Due to the large sample size of the pilot study, it was expected that the alpha values of the latent variables from the full scale study would not deviate significantly from their values in the pilot study. Table 7.1 compares the Cronbach's alpha values of the pilot study to that of the full scale study.

Table 7.1
Cronbach's Alpha Values

	Pilot Study	Full-Scale Study
Organizational Climate	0.7577	0.7594
NPD Complexity	0.7794	0.7773
CFT Support	0.8744	0.8627
CDP Support	0.8303	0.8396
CFT Diffusion Difficulty	0.6711	0.5818
CDP Diffusion Difficulty	0.8507	0.6611
Communication Quality	0.9186	0.9045
NPD Performance	0.8888	0.8887

Analyzing Table 7.1 however, it is apparent that there has been a significant drop in alpha from the pilot study to the full scale study for CFT diffusion difficulty and CDP diffusion difficulty. These alpha values, especially CFT diffusion difficulty, are only slightly above the minimal alpha of 0.562 suggested by Jackson (2003) and well below the widely cited 0.7 benchmark. As a result, the manifest variables (i.e., cost, complexity, risk) for both latent variables will be used in the forthcoming data analysis, instead of treating them as uni-dimensional variables.

7.2 Analysis of Variance

For this study, data from a number of different industries were selected. In addition, organizations within these industries operating in Canada or the United States were selected. As a result, before testing the research model, an examination must occur to determine if any of the variables in the research model differ across country (i.e., Canada and the United States), industry (i.e., NAICS Codes 333, 334, 335, 336), or organizational size.

One simple method of determining any differences between groups is by comparing the means of each group using analysis of variance (ANOVA). In the case of comparing two groups, as with country (i.e., Canada versus the United States), ANOVA produces the identical results as the simpler *t*-test (Statsoft, 2003). For this research, three ANOVA tests are required. The null hypothesis for each test is stated as follows:

- H_{anova1} : There is no difference in <variable> between Canada and the United States.
- H_{anova2} : There is no difference in <variable> across the Machinery Manufacturing (i.e., NAICS Code 333), Computer and Electronic Product Manufacturing (i.e., NAICS Code 334), Electrical Equipment, Appliance and Component Manufacturing (i.e., NAICS Code 335) and Transportation Equipment Manufacturing (i.e., NAICS Code 336) industries.
- H_{anova3} : There is no difference in <variable> between small, medium, and large organizations.

where variable = Innovative Organizational Climate, NPD Complexity, Cross-Functional NPD Team Support, Concurrent Product Development Process Support, Cross-Functional NPD Team Diffusion Difficulty, Concurrent Product Development Process Diffusion Difficulty, Communication Quality, Cross-Functional NPD Team Diffusion, Concurrent Product Development Team Diffusion, NPD Performance.

To test these hypotheses, a two (i.e., Canada and the United States) by four (i.e., NAICS codes 333, 334, 335, 336) ANOVA table is constructed in SPSS with the main effects tested, as presented in Appendix 13. Analyzing Appendix 13, it is apparent that all p -values for the main effects are greater than 0.05. Therefore, we “fail to reject” all the hypotheses for H_{anova1} , H_{anova2} , and H_{anova3} . It is thus concluded that the means of the variables used in the model do not differ by country, NAICS codes, or organization size. The data from both Canada and the United States can therefore be combined when testing the research model. In other words, there is no need to split the data and test the research model for each country, NAICS code, or size category.

7.3 Path Analysis

Multivariate regression analysis enables the researcher to estimate the form and accuracy of the relationship between several independent variables and one dependent variable. In multivariate regression analysis, a linear equation is developed using the following general form, $y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n$; where y is the predicted score of the dependent variable, a is the constant, x is the independent variable, and b is the regression coefficients and represents the contribution of the independent variable in predicting the

dependent variable, while controlling for the contribution from the other independent variables (i.e., independent contribution).

Path analysis represents an extension of multiple regression with the goal of providing estimates of the magnitude and significance of hypothesized causal connections between sets of variables (Path Analysis, 2003). Originally developed by Sewall Wright, path analysis enables the researcher to examine the direct and indirect relationship between variables. Path analysis is effective when temporal ordering of variables exist and correlation is present among variables.

To construct a path diagram, the researcher simply identifies the variables in the model and arrows indicating the direct relationship between variables. Dotted arrows indicate a negative relationship between variables. Two diagrams are required in path analysis. The input path diagram represents the proposed relationships between the model variables, while the output path diagram illustrates results of the statistical analysis.

The output path diagram contains path coefficients, which represent either the standardized partial regression coefficients, for unidirectional relationships between variables, or the Pearson product-movement correlation coefficient for correlated variables (Schumacker & Lomax, 1996). For example, referring to Figure 7.1, the path coefficients (i.e., p) illustrated by the arrows from variables X_1 to Y and X_2 to Y are stated as $\beta_1 = p_{Y,X_1}$ and $\beta_2 = p_{Y,X_2}$; while the correlation between X_1 and X_2 is represented by $r_{X_1,X_2} = p_{X_1,X_2}$.

Figure 7.1

Basic Path Analytic Model

The statistical test selected to quantitatively test the research model is path analysis. As a result of the good internal consistency of the majority of the latent variables, their means can be used to produce uni-dimensional variables. This combined with the simplicity of the model relationships makes path analysis an ideal choice for analyzing the data. As addressed earlier, instead of developing uni-dimensional variables, the manifest variables (i.e., cost, complexity, risk) for CFT and CDP Diffusion Difficulty will be used due to the relatively low internal consistency of these two constructs.

Due to the sample size and the number of manifest and latent variables in the model, a more advanced technique, specifically structural equation modelling is inappropriate, as it violates the 10-20:1 observation to model manifest variable ratio commonly suggested in the research literature and the model examines the direct relationship in various cases between latent variables (e.g., CFT Support, CDP Support, NPD Complexity) and manifest variables (e.g., CFT Diffusion, CDP Diffusion). Partial Least Squares, although may have served the purpose of this research, is also not used due to the inability of the author to acquire the appropriate software package.

Although chosen as the statistical technique to test the proposed model, path analysis also has a number of limitations that may impact this research. These limitations include most notably:

- Path analysis is most likely to be useful when we already have a clear hypothesis to test, or a small number of hypotheses all of which can be represented within a single path diagram. It has little use at the exploratory stage of research.
- We cannot use path analysis in situations where "feedback" loops are included in our hypotheses: there must be a steady causal progression across (or down) a path diagram.
- All the relationships in the path diagram must be capable of being tested by straightforward multiple regression. The intervening variables all have to serve as dependent variables in multiple regression analyses. Therefore each of them must be capable of being treated as being on an interval scale. Nominal measurement, or ordinal measurement with few categories (including dichotomies) will make path analysis impossible.
- It is clear that one can hardly draw conclusions from an analysis of 100 questionnaire items based on 10 respondents. Most authors recommend that one should have at least 10 times as many observations (cases, respondents) as one has variables, otherwise the estimates of the regression line are probably very unstable and unlikely to replicate if one were to do the study over.
- It is assumed in multiple regression [and thus in path analysis] that the residuals (predicted minus observed values) are distributed normally (i.e., follow the normal distribution).
- [Multicollinearity] is a common problem in many correlation analyses. Imagine that you have two predictors (X variables) of a person's height: (1) weight in pounds and (2) weight in ounces. Obviously, our two predictors are completely redundant; weight is one and the same variable, regardless of whether it is measured in pounds or ounces.

(Path Analysis, 2003; Statsoft, 2003)

A number of these limitations do not impact this study. Clear hypotheses have been stated, no feedback loops exist, and path analysis is being used for confirmatory, and not exploratory, research. In addition, all of the variables as they are measured on a 9-point Likert scale can be treated like ratio data.

The limitation of a small sample size is not an issue. This limitation states that there should be between 10-20 observations for each variable in the regression equation. To perform path analysis, the research model is divided into six regression equations based on the dependent variable to be tested. These dependent variables are cross-functional NPD team support (i.e., CFT Support), concurrent product development process support (i.e., CDP Support), cross-functional NPD team diffusion (i.e., CFT Diffusion), concurrent product development process diffusion (i.e., CDP Diffusion), communication quality, and NPD performance. Each regression equation contains only a few variables and are thus well above the 20:1 variable to observation ratio.

A potential limitation of using path analysis is that the residuals may not be normally distributed. To check for this problem, a histogram of the residuals will be produced for each regression equation and compared to the normal curve. Another major limitation is that multicollinearity may exist between the variables in the regression equation. Multicollinearity exists when two or more independent variables are highly correlated with one another. Wulder (2003) highlights that multicollinearity causes both logical and statistical problems:

Logically, redundant variables weaken the analysis (except in the case of factor analysis), through reduction of degrees of freedom error ... The statistical problems related to singularity and multicollinearity are related to matrix stability and ability for matrix inversion. With multicollinearity the effects are additive, the independent variables are inter-related, yet effecting the dependent variable differently. The higher the multicollinearity, the greater the difficulty in partitioning out the individual effects of independent variables. Accordingly, the partial regression coefficients are unstable and unreliable. (p. 1)

Two types of multicollinearity exist, specifically perfect and extreme. Perfect multicollinearity, also referred to as singularity, occurs when an independent variable is a perfect linear function of another variable. This occurs when a latent variable and the measurement variables that comprise it are both included in the same regression equation. Extreme multicollinearity occurs when two or more independent variables are highly, but not perfectly, correlated with one another. In extreme multicollinearity, the regression coefficient for each variable is likely to have a high standard error, thus preventing a statistically significant regression coefficient from being found and producing an unreliable regression coefficient.

There are a number of methods used to test for the presence of multicollinearity, the most common including examining the tolerance of the variables and variance inflation factor (VIF). The variance inflation factor measures the impact of multicollinearity on the regression coefficients and ranges from one to infinity. When a variable is orthogonal to the remaining variables, its VIF will equal one. A high VIF therefore indicates that a variable may be affected by multicollinearity. Researchers suggest that a VIF greater than 10 indicates the presence of multicollinearity.

The tolerance of a variable is also used to check for the presence of multicollinearity. The tolerance indicates the proportion of the variance of a variable that is not accounted for by the remaining independent variables in the regression equation, and is calculated as one minus the squared correlation of a variable with all the other variables in the regression equation.

Tolerances for a variable can range from zero to one. A value of one indicates that none of the variance in a variable has been accounted for by the remaining variables in the regression equation. Conversely, a variable with a tolerance of zero indicates all of the variance in that variable has been accounted for by the presence of the other variables in the regression equation. As a result, that variable contributes nothing to the regression equation, indicating the presence of perfect multicollinearity. Therefore, the closer the tolerance is to zero the greater the multicollinearity. This research will examine the VIF value for each variable in the regression equations, in order to identify the presence of multicollinearity.

7.3.1 Regression Equation 1: CFT Support

To perform path analysis, the research model is divided into six regression equations based on the dependent variable to be tested. These dependent variables are cross-functional NPD team support (i.e., CFT Support), concurrent product development process support (i.e., CDP Support), cross-functional NPD team diffusion (i.e., CFT Diffusion), concurrent product development process diffusion (i.e., CDP Diffusion), Communication Quality, and NPD Performance. Once each regression equation has been identified, they will be combined to form the output path analytic model.

The first equation tested is CFT Support. This research proposes that three organizational contextual factors will influence support for cross-functional teams in organizations. These factors are NPD Complexity (i.e., H_{3a}), Innovative Organizational Climate (i.e., H_{4a}), and NPD Strategy (i.e., H_{5a}). Performing regression analysis using SPSS indicates that two variables are significant at $p \leq 0.01$, specifically Innovative Organizational

Climate (i.e., CLIMATEC) and NPD Complexity (i.e., NPDCPLXC), as presented in Table 7.2.

Table 7.2
CFT Support

Model	R ²		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.258	(Constant)	2.550	.541		4.715	.000	
		CLIMATEC	.517	.079	.400	6.554	.000	1.097
		NPDCPLXC	.235	.067	.215	3.508	.001	1.099
		NPDSTRAC	.038	.123	.018	.310	.757	1.024
2	0.254	(Constant)	2.612	.502		5.200	.000	
		CLIMATEC	.519	.078	.402	6.619	.000	1.089
		NPDCPLXC	.237	.066	.216	3.563	.000	1.089

Dependent Variable: CFTSUPC

Based on Table 7.2, hypotheses regarding NPD Complexity (i.e., H_{3a}) and Innovative Organizational Climate (i.e., H_{4a}) positively influencing CFT Support are both supported at $p \leq 0.01$, while NPD Strategy (i.e., H_{5a}) positively influencing CFT Support is not supported. Together, NPD Complexity and Innovative Organizational Climate explain 25.4% of the variance in CFT Support.

Also examining Table 7.2, it is apparent that multicollinearity is not a problem as the VIF values are far below the threshold of 10 and the tolerance values are far above the threshold of 0. However, the residuals appear to be only fairly normally distributed as highlighted in Figure 7.2.

Figure 7.2

Residuals for CFT Support

7.3.2 Regression Equation 2: CDP Support

This research proposes that NPD Complexity (i.e., H_{3b}), Innovative Organizational Climate (i.e., H_{4b}), and NPD Strategy (i.e., H_{5b}) will also positively influence CDP Support. Performing regression analysis indicates that Innovative Organizational Climate (i.e., CLIMATEC), and NPD Complexity (i.e., NPDCPLXC) are significant at $p \leq 0.01$ as illustrated in Table 7.3.

Table 7.3

CDP Support

Model	R ²		Unstandardized Coefficients		Standard. Coeff.	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.288	(Constant)	2.368	.538		4.402	.000	
		CLIMATEC	.510	.075	.428	6.785	.000	1.061
		NPDCPLXC	.196	.064	.194	3.056	.003	1.071
		NPDCSTRAC	.227	.118	.119	1.915	.057	1.022
2	0.259	(Constant)	2.851	.499		5.715	.000	
		CLIMATEC	.503	.075	.418	6.721	.000	1.055
		NPDCPLXC	.211	.062	.210	3.373	.001	1.055

a Dependent Variable: CDPSUPC

Based on Table 7.3, the hypotheses stating that NPD Complexity (i.e., H_{3b}) and Innovative Organizational Climate (H_{4b}) positively influence CDP Support are both supported at $p \leq 0.01$, while the hypothesis suggesting that NPD Strategy positively influences CFT Support (i.e., H_{5b}) is only marginally supported. Together, Innovative Organizational Climate and NPD Complexity explain 25.9% of the variance in CDP Support. In addition, examining Figure 7.3, it is apparent that the residuals are normally distributed.

Figure 7.3

Residuals for CDP Support

7.3.3 Regression Equation 3: CFT Diffusion

The third equation in the path model examines the direct determinants of CFT Diffusion. These organizational contextual factors include CFT Diffusion Difficulty (i.e., H_{1a}) and CFT Support (i.e., H_{2a}). As stated earlier, the manifest variables for CFT Diffusion Difficulty will be used in the regression equation due to its low internal consistency. These manifest variables are the cost (i.e., $COSTCFT$), complexity (i.e., $CPLXCFT$), and risk (i.e., $RISKCFT$) of using cross-functional NPD teams. Performing regression analysis highlights that CFT Support (i.e., $CFTSUPC$) and the complexity of using cross-functional NPD teams (i.e., $CPLXCFT$) are both significant at $p \leq 0.01$, as indicated in Table 7.4.

Table 7.4

CFT Diffusion

Model	R ²		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.311	(Constant)	14.231	10.747		1.324	.187	
		CFTSUPC	11.354	1.343	.548	8.451	.000	1.255
		COSTCFT	-.484	1.066	-.029	-.454	.651	1.249
		CPLXCFT	-2.803	1.100	-.174	-2.548	.012	1.401
		RISKCFT	-.275	1.161	-.016	-.237	.813	1.377
2	0.311	(Constant)	13.022	9.440		1.380	.169	
		CFTSUPC	11.485	1.222	.554	9.400	.000	1.043
		COSTCFT	-.509	1.058	-.031	-.482	.631	1.236
		CPLXCFT	-2.899	1.022	-.180	-2.835	.005	1.215
3	0.310	(Constant)	12.089	9.222		1.311	.191	
		CFTSUPC	11.398	1.206	.550	9.451	.000	1.020
		CPLXCFT	-3.096	.935	-.193	-3.311	.001	1.020

a Dependent Variable: PRUSECF2

As a result, the hypothesis proposing that CFT Support positively influences CFT Diffusion (i.e., H_{2a}) is supported. The hypothesis that CFT Diffusion Difficulty negatively influences CFT Diffusion (i.e., H_{1a}) is partially supported. More specifically, the complexity of using cross-functional NPD teams (i.e., CFT Complexity) negatively influences its diffusion. Together CFT Support and CFT Complexity explain 31% of the variance in CFT Diffusion. In addition, the regression residuals appear to be fairly normally distributed, as presented in Figure 7.4.

Figure 7.4

Residuals for CFT Diffusion

7.3.4 Regression Equation 4: CDP Diffusion

Regression equation four examines the direct determinants influencing the diffusion of concurrent product development processes in organizations. The proposed organizational contextual factors are CDP Diffusion Difficulty (i.e., H_{1b}) and CDP Support (i.e., H_{2b}). As with CFT Diffusion Difficulty, the manifest variables of CDP Diffusion Difficulty (i.e., COSTCDP, CPLXCDP, RISKCDP) are used in the regression model. Results of performing regression analysis (i.e., Table 7.5) indicates that only one variable is significant, specifically CDP Support (i.e., CDPSUPC) at $p \leq 0.01$.

Table 7.5

CDP Diffusion

Model	R ²		Unstandardized Coefficients		Stand. Coeff.	t	Sig.	Collinearity Statistics
			B	Std. Error				
1	0.186	(Constant)	-16.854	18.516		-.910	.364	
		CDPSUPC	12.094	2.228	.394	5.427	.000	.877
		COSTCDP	-.416	1.556	-.020	-.267	.790	.814
		CPLXCDP	-1.059	1.775	-.052	-.596	.552	.614
		RISKCDP	-1.154	1.559	-.063	-.740	.460	.634
2	0.186	(Constant)	-17.600	18.255		-.964	.336	
		CDPSUPC	12.053	2.218	.393	5.436	.000	.881
		CPLXCDP	-1.229	1.652	-.060	-.744	.458	.705
		RISKCDP	-1.166	1.554	-.064	-.750	.454	.635
3	0.183	(Constant)	-20.168	17.904		-1.126	.261	
		CDPSUPC	11.844	2.197	.386	5.391	.000	.895
		RISKCDP	-1.790	1.307	-.098	-1.369	.173	.895
4	0.174	(Constant)	-33.849	14.894		-2.273	.024	
		CDPSUPC	12.817	2.084	.418	6.151	.000	1.000

a Dependent Variable: PRUSECD2

As a result, the hypothesis that CDP Support positively influences CDP Diffusion (H_{1b}) is supported. The hypothesis that CDP Diffusion Difficulty negatively influences CDP Diffusion (H_{2b}) is not supported. Concurrent Product Development Support explains 17.4% of the variance in CDP Diffusion. However, the residuals appear to be only marginally normally distributed, as shown in Figure 7.5.

Figure 7.5

Residuals for CDP Diffusion

7.3.5 Regression Equation 5: NPD Performance

Regression equation five tests the relationship between CFT Diffusion (i.e., H_{7a}), CDP Diffusion (i.e., H_{7b}), and NPD Performance. Examining the SPSS output presented in Table 7.6, it is apparent that both variables are significant at $p \leq 0.05$.

Table 7.6

NPD Performance

Model	R ²		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.055	(Constant)	5.587	.130		42.920	.000	
		PRUSECF2	.004	.002	.132	1.999	.047	1.235
		PRUSECD2	.004	.002	.145	2.185	.030	1.235

a. Dependent Variable: NPDPERC

In addition, the residuals appear to be normally distributed, as highlighted in Figure 7.6.

Figure 7.6

Residuals for NPD Performance

As a result, the hypotheses that CFT Diffusion (H_{7a}) and CDP Diffusion (H_{7b}) positively influence NPD Performance are statistically supported. However, although both CFT and CDP Diffusion are both statistically significant, they do very little in explaining the variance of NPD Performance, with a combined r^2 of only 0.055 or 5.5% of the variance explained.

7.3.6 Regression Equation 6: Communication Quality

The final regression equation required to test the research model involves examining how CFT Diffusion (i.e., H_{8a}) and CDP Diffusion (i.e., H_{8b}) influence Communication Quality. Performing regression analysis using SPSS, Table 7.7 highlights that both variables are significant at $p \leq 0.01$.

Table 7.7
Communication Quality

Model	R ²		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.271	(Constant)	4.544	.149		30.397	.000	
		PRUSECF2	.013	.002	.354	6.070	.000	1.233
		PRUSECD2	.008	.002	.258	4.434	.000	1.233

a. Dependent Variable: QUALITYC

The hypotheses that CFT Diffusion (i.e., H_{8a}) and CDP Diffusion (i.e., H_{8b}) positively influences Communication Quality are therefore supported. Together, both variables explain 27.1% of the variance in Communication Quality. In addition, results of the regression analysis indicate a lack of multicollinearity between the variables and normally distributed residuals, as highlighted in Table 7.7 and Figure 7.7, respectively.

Figure 7.7

Residuals for Communication Quality

Histogram

Dependent Variable: QUALITYC

7.4 Initial Model of IPD Diffusion

As previously stated, developing the output path analytic model requires stating the path coefficients, which represent either the standardized partial regression coefficient or the Pearson product-movement correlation coefficient. The standardized partial regression coefficients for each regression equation are stated in Tables 7.2 through to 7.7. Representing this information graphically, Figure 7.8 illustrates the initial output path analytic model for this research.

Figure 7.8

Initial Model of IPD Diffusion

7.5 Revised Model of IPD Diffusion

The model illustrated in Figure 7.8 identifies relationships between CFT and CDP Diffusion and NPD Performance. However, the data provides very little support for these relationships, with CFT and CDP Diffusion collectively explaining only 5.5 % of the variance in NPD Performance. Based on this low r^2 , these two relationships are dropped,

initiating a search for a better model. To determine if a better model can be developed, various regression analyses were run using the variables in the initial model, but ignoring any proposed relationships. In addition, a correlation matrix was developed to examine correlations between those variables where a direct relationship was not stated in the initial model.

Results of performing various regression analysis scenarios and examining various correlation matrices highlight two major areas where the model could be improved. The first improvement involves the relationship between CFT Diffusion, CDP Diffusion, Communication Quality and NPD Performance. The low r^2 for both CFT and CDP Diffusion in explaining NPD Performance suggests that these two former variables may not directly influence NPD Performance.

Results of performing various regression analysis scenarios on these two variables plus Communication Quality and NPD Performance, suggests that CFT and CDP Diffusion may instead indirectly improve NPD Performance by improving the quality of communication between the various functional disciplines involved in developing new products in the organization (i.e., Communication Quality). Performing regression analysis (i.e., Table 7.8) between Communication Quality (i.e., independent variable) and NPD Performance (i.e., dependent variable) suggests that this may indeed be the case.

Table 7.8

Revised NPD Performance

Model	R ²		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.269	(Constant)	3.707	.241		15.374	.000	
		QUALITYC	.397	.040	.518	9.882	.000	1.000

a. Dependent Variable: NPDPERC

Results of performing this regression analysis shows that Communication Quality is significant at $p \leq 0.01$ and explains 26.9% of the variance in NPD Performance. In addition, results of the regression analysis indicate that the residuals are normally distributed, as highlighted in Figure 7.9.

Figure 7.9

Residuals for NPD Performance

The second area of improvement is the relationship between Innovative Organizational Climate (i.e., CLIMATEC) and Communication Quality (i.e., QUALITYC). Performing regression analysis on Communication Quality using CFT Diffusion, CDP Diffusion, and Innovative Organizational Climate, shows all three variables significant at $p \leq 0.01$ and that 40.6% of the variance in Communication Quality is explained; an improvement of 13.5% over the Communication Quality regression equation with Innovative Organizational Climate omitted (i.e., Table 7.7). In addition, the residuals appear to be fairly normally distributed, as presented in Figure 7.10.

Table 7.10

Regression for Communication Quality

Model	R ²		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.406	(Constant)	2.256	.325		6.943	.000	
		CLIMATEC	.420	.054	.383	7.747	.000	1.086
		PRUSECF2	.012	.002	.325	6.164	.000	1.239
		PRUSECD2	.005	.002	.166	3.066	.002	1.297

a. Dependent Variable: QUALITYC

Figure 7.10

Residuals for Communication Quality

Histogram

Dependent Variable: QUALITYC

Incorporating these two modifications into the research model, Figure 7.11 presents a revised model of IPD diffusion.

Figure 7.11

Revised Model of IPD Diffusion

To determine the overall fit of the revised model to the data the q statistic is used, as it is fairly easy to calculate and therefore does not require sophisticated structural equation modeling software such as LISREL or AMOS to calculate. The q statistic compares the just-identified model (i.e., one with all possible relationships in it) to an over-identified one (i.e., one containing only the statistically significant relationships). The closer q is to one, the better the model fits the data. The q statistic is calculated as follows:

$$q = (1 - r_m^2) / (1 - m)$$

Where r_m^2 is the generalized squared multiple correlation coefficient for the just-identified model and m is the generalized squared multiple correlation coefficient for the over-identified model. r_m^2 and m are calculated as follows:

$$r_m^2 = 1 - (1 - r_1^2)(1 - r_2^2) \dots (1 - r_p^2)$$

;where the r^2 values represent the squared multiple correlation coefficients from each of the separate regression analysis.

$$m = 1 - (1 - r_1^2)(1 - r_2^2) \dots (1 - r_p^2)$$

;where the r^2 values represent the squared multiple correlation coefficients from each of the separate regression analysis, keeping only significant coefficients.

The r^2 for the just-identified model involves performing regression analysis and taking the variance explained, including both the significant and non-significant variables and considering the indirect relationships as direct ones. For example, in calculating the r^2 for the r_m^2 (i.e., over-identified model) equation for CFT Support, Innovative Organizational Climate, NPD Complexity, and NPD Strategy would all be considered. However, in calculating the r^2 for the m (i.e., just-identified model) equation, NPD Strategy would not be considered as it is not significant and has thus been dropped from

the revised model. Applying this formula to the revised model yields a q value of 0.6, as highlighted in Table 7.11.

Table 7.11

Test of Model Fit

Dependent Variables		r^2 for r_m^2	r^2 for m
Revised Model	CFT Support	0.258	0.254
	CDP Support	0.288	0.259
	CFT Diffusion	0.330	0.310
	CDP Diffusion	0.186	0.174
	Communication Quality	0.520	0.406
	NPD Performance	0.401	0.269
Model Fit			
r_m^2		0.917	
m			0.863
q			0.61

The closer q is to 1, the better the model fits the data. Therefore, a q of 0.61 indicates that only a fair model fit to the data exists. Although, this number seems low, one must remember that only a few organizational contextual factors are examined in this study (i.e., nine in the revised model). Other factors such as NPD team (e.g., team autonomy) and environmental (e.g., use of IPD by suppliers and competitors) determinants of IPD diffusion have not been considered. It is expected that many of these factors also play a significant role in IPD diffusion. However, with a q of 0.61 and using only nine variables, the model does a good job in accounting for the impact of organizational contextual factors on IPD diffusion.

To determine the relative importance of each variable, the variance in the dependent variables explained by each individual independent variable can be examined. To calculate the variance explained by each variable, Jackson (2003) suggests using a formula developed by Hamblin (1966), specifically:

$$((|B_1| * r^2) / |\sum B_s|) * 100$$

; where B_1 is the beta coefficient of the variable of interest, r^2 is the total variance explained, $|\sum B_s|$ is the sum of the absolute value of the beta coefficients.

Applying this formula to each regression equation used to develop Figure 7.11, Table 7.12 indicates the amount of variance in the dependent variable explained by each independent variable.

Table 7.12

Variance Explained By Independent Variables – Revised Model

	Independent Variables	Direction	r^2
CFT Support	Climate	+	0.165
	NPD Complexity	+	0.089
CDP Support	Climate	+	0.172
	NPD Complexity	+	0.087
CFT Diffusion	CFT Support	+	0.230
	CFT Complexity	-	0.081
CDP Diffusion	CDP Support	+	0.174
NPD Performance	Com. Quality	+	0.269
Communication Quality	CFT Diffusion	+	0.151
	CDP Diffusion	+	0.078
	Climate	+	0.178

The next step to developing an output path analytic model is to add the residual error terms to the dependent variables in the model. Residual error terms are calculated using the following formula.

$$p_e = \sqrt{(1 - r^2)}$$

Applying this formula to the dependent variables in the revised model results in the residual error terms presented in Table 7.13.

Table 7.13

Residual Error Terms for the Revised Model

	r^2	p_e
CFT Support	0.254	0.864
CDP Support	0.259	0.861
CFT Diffusion	0.310	0.830
CDP Diffusion	0.174	0.908
Communication Quality	0.406	0.771
NPD Performance	0.269	0.855

With the residual error terms calculated, an examination of the correlation between CFT and CDP Support can occur. This research proposes that high levels of support for cross-functional NPD teams will be positively associated with high levels of support for concurrent product development processes, and vice-versa (i.e., H_{2c}). To test this relationship, the correlation between CFT Support and CDP Support must be examined. One of the advantages of path analysis is that it allows the researcher to decompose the sources of correlation between variables, instead of simply calculating the Pearson product movement correlation, which tells very little as to why the variables may be correlated.

To calculate the total correlation between variables in a path analytic model, the direct and indirect correlations between the two variables of interest are needed. In addition, the variables residual error terms and the correlation between the variable's residuals are also needed. Examining Figure 7.11, only the direct correlation between CFT Support and CDP Support can be captured as only direct paths exist between these two variables in

the model. These paths are from: i.) CFT Support backwards to NPD Complexity and then forward to CDP Support and ii.) CFT Support backwards to Innovative Organizational Climate and forward to CDP Support, as illustrated in Figure 7.12.

Figure 7.12
Correlation Paths

To calculate these direct correlations, the standardized correlation coefficients on the paths are multiplied together. To calculate the contribution from the residuals to the correlation, the Pearson product movement correlation is multiplied by the residual error terms for CFT and CDP Support. Using SPSS, the Pearson product movement correlation for the residuals of CFT and CDP Support is presented in Table 7.14.

Table 7.14

Correlation of Residuals

		Standardized Residual	Standardized Residual
Standardized Residual	Pearson Correlation	1	.625(**)
	Sig. (2-tailed)	.	.000
Standardized Residual	Pearson Correlation	.625(**)	1
	Sig. (2-tailed)	.000	.
** Correlation is significant at the 0.01 level (2-tailed).			

The correlation between CFT and CDP Support is therefore decomposed as follows:

Table 7.15

Decomposition of CFT and CDP Correlation

	Source	Amount	Total
Direct			
	Organizational Climate	$(0.402)0.418 = 0.168$	
	NPD Complexity	$(0.216)0.210 = 0.045$	
		Total Direct	0.213
Indirect			
	n/a	--	
		Total Indirect	--
Residual			
		$(0.864)0.861(0.625) = 0.464$	
		Total Residual	0.465
Total			
		Total Correlation	0.68

The total correlation between CFT Support and CDP Support is fairly high at 0.68. The hypothesis that the level of support for cross-functional NPD teams is positively associated with the level of support for concurrent product development processes (i.e., H_{2c}) is therefore supported. As this correlation is below the benchmark of $|0.8|$ suggested by Allen (1997), multicollinearity is not a problem. This lack of multicollinearity is also highlighted in Table 7.10, where the regression of CFT

Diffusion, CDP Diffusion, and Innovative Organizational Climate on Communication Quality possesses VIF (i.e., 1.086 - 1.297) values well within the acceptable range.

Incorporating the residual error terms (i.e., p_e) and the correlation between CFT Support and CDP Support into the revised model, Figure 7.13 illustrates the final model of the determinants and performance consequences of IPD diffusion.

Figure 7.13

Determinants and Performance Consequences of IPD Diffusion

Based on this final model, the hypotheses proposing that CFT Diffusion (H_{6a}) and CDP Diffusion (H_{6b}) directly influence NPD Performance are no longer supported. Table 7.16 summarizes the 15 hypotheses developed for this research study and those that are supported and not supported by the final model.

Table 7.16

Supported and Non-Supported Hypotheses

	Hypotheses	Support
H_{1A}	Cross-functional NPD team diffusion difficulty will negatively influence the extent of diffusion of cross-functional NPD teams.	Partial (i.e., CFT Complexity), $p \leq 0.01$
H_{1B}	Concurrent product development process diffusion difficulty will negatively influence the extent of diffusion of concurrent product development processes.	No
H_{2A}	Organizational member support for cross-functional NPD teams will positively influence the extent of diffusion of cross-functional NPD teams.	Yes, $p \leq 0.01$
H_{2B}	Member support for concurrent product development processes will positively influence the extent of diffusion of concurrent product development processes.	Yes, $p \leq 0.01$
H_{2c}	The level of support for cross-functional NPD teams will be positively associated with the level of support for concurrent product development processes, and vice-versa.	Yes, $p \leq 0.01$
H_{3A}	NPD complexity will positively influence organizational support for cross-functional NPD teams.	Yes, $p \leq 0.01$
H_{3B}	NPD complexity will positively influence organizational support for concurrent product development processes.	Yes, $p \leq 0.01$
H_{4A}	An innovative organizational climate will positively influence cross-functional NPD team support.	Yes, $p \leq 0.01$
H_{4B}	An Innovative organizational climate will positively influence concurrent product development process support.	Yes, $p \leq 0.01$
H_{5A}	An NPD strategy focused on turning out new products will positively influence the organizational support for cross-functional NPD teams.	No
H_{5B}	An NPD strategy focused on turning out new products will positively influence the organizational support for concurrent product development processes.	No
H_{6A}	The extent of cross-functional NPD team diffusion will positively influence the NPD performance of Canadian and American manufacturers.	Statistical significance but no practical significance
H_{6B}	The extent of concurrent product development process diffusion will positively influence the NPD performance of Canadian and American manufacturers.	Statistical significance but no practical significance
H_{7A}	The extent of cross-functional NPD team diffusion will positively influence the quality of cross-functional NPD teams.	Yes, $p \leq 0.01$
H_{7B}	The extent of concurrent product development process diffusion will positively influence the quality of concurrent processes.	Yes, $p \leq 0.01$

7.6 Interaction Effect of IPD Practices

As previously stated, Gerwin and Barrowman (2002) make a number of recommendations for future research studies that explore integrated product development. These major recommendations include using more than simply development time to capture NPD Performance, examining the extent of diffusion of IPD, and examining the interaction between various IPD practices. The final model developed in the previous section addresses the former two points. To examine the interaction between IPD practices, the scores for CFT Diffusion must be multiplied by the scores for CDP Diffusion to produce a new interaction variable.

The impact of this interaction variable on Communication Quality and NPD Performance must be examined separately from the final model presented in Figure 7.12. The reasoning is that since the interaction variable (i.e., CFT Diffusion $\times$ CDP Diffusion) and the variables used to construct that variable (i.e., CFT Diffusion, CDP Diffusion) would all enter into the same model, high multicollinearity would occur, producing unstable path coefficients, as illustrated in Table 7.17.

Table 7.17

Coefficient Stability

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	5.638	.317		17.812	.000		
	PRUSECF2	.001	.005	.037	.243	.808	.214	4.680
	PRUSECD2	.001	.006	.029	.141	.888	.124	8.062
	COMPUTE Interact = prusecf2 * prusecd2 (COMPUTE)	4.859E-05	.000	.185	.648	.518	.063	15.957
2	(Constant)	5.672	.204		27.761	.000		
	PRUSECF2	.001	.004	.026	.198	.843	.302	3.308
	COMPUTE Interact = prusecf2 * prusecd2 (COMPUTE)	5.802E-05	.000	.220	1.704	.090	.302	3.308
3	(Constant)	5.703	.135		42.346	.000		
	COMPUTE Interact = prusecf2 * prusecd2 (COMPUTE)	6.366E-05	.000	.242	3.409	.001	1.000	1.000

The results of analyzing the interaction effect of CFT Diffusion and CDP Diffusion on NPD Performance is presented in Table 7.18 and Figure 7.13.

Table 7.18

Interaction of CFT and CDP Diffusion on NPD Performance

Model	R ²		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.059	(Constant)	5.703	.135		42.346	.000	
		COMPUTE INTERACT = prusecf2 * prusecd2 (COMPUTE)	6.366E-05	.000	.242	3.409	.001	1.000

a Dependent Variable: NPDPERC

Figure 7.13

Residuals for Interaction Effect on NPD Performance

Analyzing Table 7.17, it is apparent that the interaction variable (i.e., INTERACT) significantly influences NPD Performance with a p -value of less than 0.01. In addition, the residuals are normally distributed. However, as with CFT Diffusion and CDP Diffusion, the variance in NPD Performance explained by this interaction variable is very low at 5.9% and only marginally above the sum of CFT Diffusion and CDP Diffusion at 5.5%.

In Section 7.5 it was found that instead of CFT and CDP Diffusion directly influencing NPD Performance, CFT and CDP Diffusion directly influences Communication Quality which, in turn, influences NPD Performance. As with CFT and CDP Diffusion, the relationship between the interaction variable and Communication Quality is tested with the results highlighted in Table 7.19 and the residuals illustrated in Figure 7.14.

Table 7.19

Interaction of CFT and CDP Diffusion on Communication Quality

Model	R ²		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
			B	Std. Error	Beta			VIF
1	0.374	(Constant)	2.964	.366		8.104	.000	
		CLIMATEC	.368	.059	.368	6.193	.000	1.046
		COMPUTE INTERACT = prusecf2 * prusecd2 (COMPUTE)	.384E-04	.000	.417	7.004	.000	1.046

a. Dependent Variable: QUALITYC

Figure 7.14

Residuals for the Interaction Effect of CFT and CDP Diffusion

The interaction variable (i.e., INTERACT) combined with an Innovative Organizational Climate together explain 37.4% of the variance in Communication Quality, a drop from 40.6% when CFT and CDP Diffusion are considered separately. Decomposing this variance indicates that the interaction variable explains 19.9% of the variance in Communication Quality and is slightly below the summed variance explained of CFT Diffusion and CDP Diffusion at 22.9%. In addition, the residuals are only marginally normally distributed.

CHAPTER VIII

DISCUSSION

8.1 Introduction

This research examines the diffusion of IPD within Canadian and American manufacturing organizations by presenting three investigative questions, specifically:

- What organizational contextual factors influence the extent of IPD diffusion within Canadian and American manufacturing organizations?
- How does communication quality change with the extent of IPD diffusion within Canadian and American manufacturing organizations?
- How does NPD performance change with the extent of IPD diffusion within Canadian and American manufacturing organizations?

To answer these investigative questions, a research model was developed in Chapter Three. This initial research model proposed that IPD diffusion would be significantly influenced by the actual, required, and ease of integration between the functional disciplines involved in new product development. The resulting organizational contextual factors were categorized as either direct or indirect determinants depending upon their proposed relationship to IPD diffusion.

The direct determinants include support for the IPD practices and their difficulty of diffusion, while the indirect determinants include the complexity of the organization's NPD activities, the climate of the organization, and the organization's NPD strategy. Finally, the research model proposed that IPD diffusion would positively influence both the NPD performance of the organization and the quality of communication between the functional disciplines involved in new product development.

The final research model developed in Chapter Seven deviates from the proposed research model. Of the diffusion difficulty manifest variables, only the complexity of cross-functional NPD teams negatively influences diffusion. It appears that the NPD strategy does not influence IPD diffusion; neither indirectly nor directly. In addition, an innovative organizational climate directly and significantly influences support for both IPD and the quality of communication between the functional disciplines involved in new product development. The final model also indicates an indirect relationship between IPD practices and NPD performance, via the presence of a new moderating variable, specifically communication quality.

The final research model answers all three investigative questions posed by this study. The first investigative question aims to identify the determinants of IPD diffusion. The research model highlights that organizational contextual factors may influence IPD diffusion in two ways. First, practice support and complexity, in the case of cross-functional NPD teams, directly influence IPD diffusion. Second, NPD complexity and an innovative organizational climate indirectly influence IPD diffusion, by influencing support for IPD practices in the organization.

The goal of the second question is to identify the relationship between IPD diffusion and communication quality. This study found that the extent of IPD diffusion positively influences the quality of communication between the functional disciplines involved in product development. It was also found that communication quality is influenced by an innovative organizational climate and significantly more so than IPD diffusion.

The third investigative question explores the relationship between IPD diffusion and NPD performance. This research found an indirect relationship between IPD diffusion and NPD performance. Integrated product development diffusion combined with an innovative organizational climate influences communication quality, which in turn, influences NPD performance.

The remainder of Chapter Eight discusses the final research model. This chapter examines in detail the qualitative data (i.e., managerial comments) captured by this research, explores why various model components are, or are not, supported by the quantitative and qualitative data, identifies where this model deviates from the work of other researchers, and discusses the implications of the model components to both researchers and managers alike.

8.2 Diffusion of Integrated Product Development

Examining the large volume of literature in the area, it becomes apparent rather quickly that IPD plays a critical role in helping organizations achieve their product development objectives. The importance of IPD for successful NPD is not only widely recognized by researchers but also by NPD managers; as highlighted by selected comments taken from the open-ended section of the questionnaire.

- There is no other way to pursue new product development.
- We call it Common Sense Engineering. It only makes sense to use all your resources when bringing a product out or improving an existing one. It also improves your speed to the market.

- We used to have a saying in our organization that we never had time to do it right, but always had time to do it over, this view typified our approach in the early 1990's. We invested in concurrent engineering and acquired some tools to support planning and committed to the program. We now do things faster, with less waste and can support timing nearly all the time. The quality of life of our teams has significantly improved over the years. Our system is an open system that is 80% planning and 20% implementation with the CAD, process simulation tools, mold flow, DFA, DFMEA and process FMEA we can brain storm what are the things that will go wrong or where are the risks and we now have contingency plans or refinements in place before the tooling is built rather than a reaction to the first shots.
- CE is the best way of focusing the organizations knowledge to develop a new product in a timely manner which meets the demands of the market.
- It [IPD] often results in [a] product being changed after going into production. Yet it is the only way to go.
- Cross-functional teams and concurrent engineering processes are absolute requirements for successful NPD today. Competitive speed to market can not be realized without them. Overall quality of the end product is also improved by having all the users of the product engaged in the NPD process.
- CE is the best way of focusing the organizations knowledge to develop. It is now so second nature to our company we would not consider working any other way. We make components (very expensive ones!) and so sales and various other disciplines do not need to be involved in our process, but in our process documentation and in our practices, everyone with interest in the product is involved.
- As indicated in the survey, our organization uses concurrent engineering on all projects. It is a must if projects are to be done in a reasonable time frame. Time to market in our industry is critical and must be short to be competitive.
- My personal experience with concurrent NPD has been extremely rewarding, and in at least one large NPD project it was credited with achieving our production introduction deadline.

Although these comments emphasize the benefits of IPD, various managerial comments also suggest many problems associated with using integrated product development. The commonly cited problems of using cross-functional NPD teams obtained from the qualitative data of this study include the time and cost of resources required to make these teams effective, competing agendas among members of cross-functional NPD

teams, and competition for resources between the various functional disciplines. The commonly cited problems of concurrent development processes include increased development costs, increase in rework, and poor communication between functional disciplines.

In addition to these problems, more interesting, albeit not widely cited, problems of IPD include functional disciplines, such as manufacturing, not being measured on their NPD involvement or performance, team members using IPD for their own personal advantage, people brought in from other functional disciplines not prepared for the failure associated with NPD, and employee difficulty in juggling the workload of their functional discipline and NPD team; as presented by the following managerial comments:

- Concurrent Engineering in concept works. With today's lean environments, it is difficult for less involved participants to do both their normal responsibilities and development also. We just don't have enough resources to do both well. [Manufacturing] wants to be involved more with R&D, but their primary goal is to make on time delivery of existing product. This is what they are measured on, not concurrent engineering.
- It often seems one or two individuals have learned to use cross-functional teams as a way to play both side of a new development. They take up whatever is the opposite position so if a project fails they can say told ya so and if it is a success they can get credit as a part of the team.
- There are risks with concurrent engineering; 1) more inertia in the project meaning that changes effect more people and are difficult to execute. 2) Psychologically, non-technical depts. are typically frustrated if they are brought into the project during the trial and error phase. Few professionals are prepared for the amount of failure involved in any NPD that launches a first-of-its-kind product. 3) Marketing is typically short of resources; therefore, most ideas for NPD projects actually come from the development engineers working with input (daily) from sales.
- Cross-Functional Teams are desirable, however it is extremely difficult for employees to complete their daily workload as well as attend meetings and [participate] in trials.

These comments highlight potential issues which may slow or prevent the diffusion of IPD in organizations, and therefore those of concern for NPD managers. Based on the qualitative data presented above, steps that senior managers can undertake to reduce the problems associated with IPD diffusion include providing adequate funds to ensure that IPD can be maintained in the organization, and developing performance measures for the functional disciplines involved in NPD that include some NPD component. Steps that NPD managers, in conjunction with functional managers, can take to reduce the problems of IPD diffusion include preparing non-design team members for the possible failures that often occur when developing radical innovations and balancing employee workload between the NPD team and their respective functional discipline.

Despite these potential problems, the diffusion of IPD in organizations is quite high. The prevalence of IPD in the organizations addressed by this research study approximates other similar NPD studies. Eighty-seven percent of the responding organizations use cross-functional NPD teams. This represents a slight increase in intensity when compared to the earlier studies of Trygg (1993) and Griffin (1997), confirming that cross-functional NPD team usage is gradually increasing.

A review of the literature failed to identify studies that specifically measure the intensity of concurrent product development processes. This study confirms that the usage of concurrent development processes slightly trails that of cross-functional NPD teams, and is used in approximately 77% of the responding organizations. Approximately 70% of the organizations used both cross-functional NPD teams and concurrent product development

processes when developing new products, while 24% used both practices 100% of the time. Organizations pursuing IPD are thus likely to be doing so using multiple practices. The correlation between the diffusion of cross-functional NPD teams and concurrent development processes is fairly low at $r = 0.436$ ($p \leq 0.01$). This low correlation suggests that although organizations are using multiple practices to achieve IPD, these practices are likely to be at different stages of diffusion.

It is apparent that managers have realized the importance of integrated product development for successful NPD, as highlighted by the large number of organizations already using IPD practices, usage of multiple IPD practices, increases over the past several years of cross-functional NPD team usage, and management comments. Although this research suggests that the use of IPD is on the rise, it is still, for many organizations, not used on all NPD projects. For example, this research confirms that approximately 24% of organizations use both cross-functional NPD teams and concurrent product development processes on all NPD projects. Although this number seems high, one must consider why the remaining 76% of organizations are not using these IPD practices at the same level of diffusion.

8.3 Direct Determinants of IPD Diffusion

To address why many organizations are not extensively diffusing IPD, this study examines the interrelationship between those organizational contextual factors that create the need for IPD, those factors that facilitate IPD diffusion, and those factors that hamper or prevents IPD diffusion within the organization. These organizational contextual factors either i) directly influence IPD diffusion or ii) indirectly influence IPD diffusion by

influencing support for IPD; and are grouped as direct and indirect determinants of IPD diffusion, respectively. The direct determinants of IPD diffusion are practice diffusion difficulty and IPD support.

8.3.1 Practice Diffusion Difficulty

Practice diffusion difficulty captures the difficulty of implementing a specific IPD practice in the organization. Practice diffusion difficulty is specific to each practice and is captured by the risk, complexity, and cost of the individual practices selected to achieve integrated product development

Based on the innovation literature (e.g., Meyers & Goes, 1988; Wolfe, 1994) it was expected that the greater the practice diffusion difficulty for a specific IPD practice, the less it would be diffused in the organization. Results of the data analysis however found that only the complexity of using cross-functional NPD teams negatively influences CFT diffusion. The complexity, risk, and cost of using concurrent product development processes do not influence its diffusion. In addition, the relationship between CFT complexity and cross-functional NPD team diffusion is not as strong as the current research literature may suggest, explaining only 8.1 % of the variance in cross-functional NPD team diffusion.

The lack of a significant relationship between CDP cost, complexity, and risk and diffusion and the marginal variance explained in CFT diffusion by CFT complexity highlights that these practice attributes are not major factors in the diffusion of IPD in organizations. Examining Table 8.1, it is apparent that these practices are only viewed to

be moderately expensive, complex, and risky to use, with mean values close to the mid-point on the survey.

Table 8.1
CFT and CDP Cost, Risk, and Complexity

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
COSTCFT	222	1.00	9.00	4.9730	1.8809
COSTCDP	190	1.00	9.00	4.7211	2.0135
CPLXCFT	233	1.00	9.00	5.0644	1.9298
CPLXCDP	201	1.00	9.00	5.2065	2.0294
RISKCFT	221	1.00	9.00	3.2534	1.8214
RISKCDP	192	1.00	9.00	3.8281	2.2713
Valid N (listwise)	164				

The moderate risk, cost, and complexity of these two practices may explain why they do not significantly influence IPD diffusion. Based on the qualitative data, it is derived that the perceived benefits of using IPD are well known to NPD managers. As a result, it is expected that the perceived benefits of using IPD practices may significantly outweigh the moderate costs, risks, and complexity associated with their diffusion. This view is supported by the following comment from an NPD manager.

- It [IPD] can increase costs initially but those costs can be offset by getting your product to the market sooner. The end result is almost always a better product, made more efficiently, with better quality.

In cases of low to moderate levels of cost, risk, or complexity, IPD diffusion is unaffected. However, based on comments from managers, it appears that when NPD practices are viewed as very complex, expensive, or risky they do influence IPD diffusion.

- Our vision is certainly aimed at maximum concurrency. Slowly we are migrating our processes to align in parallel. Often the perception that concurrency results in low cost, not so! Speed through concurrency is not cheap and is riddled with risk. Concurrency is good to drive speed, but risk and project cost must be considered when applying.
- Time and people usually hinder the efforts of concurrent engineering. The demand for NPD is usually so traumatic that compromising is required. May be more productive in terms of completion. Lends itself to high stress & total costs.

Based on the qualitative data, it appears that practice diffusion difficulty is not a major factor in deciding whether or not to use IPD on an NPD project, except under conditions of high cost, risk, or complexity. Unfortunately, this finding cannot be quantitatively verified using ANOVA, as not enough companies indicated that their IPD practices were of high complexity, cost, or risk (e.g., ≥ 8 on the likert scale)⁵.

8.3.2 Member Support

Organizational member support measures the extent that various members of the organization support the ongoing use of IPD in the organization and is captured by senior management, departmental, and employee support for integrated product development. It was expected that organizational member support would positively influence the extent of diffusion of IPD, as IPD would be easier to implement when the use of IPD is supported by members of the organization.

⁵ Of the 269 responding organizations, the number of organizations that found the cost, complexity, and risks of using cross-functional NPD teams high (i.e., ≥ 8) were 22, 23, and 6, respectively. The number of organizations that found the cost, complexity, and risks of using concurrent product development process high were 18, 24, and 14, respectively.

Based on the percentage of variance in IPD diffusion explained by this construct (i.e., 23 % for CFT Diffusion and 17.4% for CDP Diffusion), it appears that obtaining support for IPD is one of the most important steps managers can take to infuse IPD into the organization, especially in the case of cross-functional NPD teams. Possible reasons why member support is important are highlighted in Chapter Three and include, for example:

- Support for IPD at the senior level enables team members to achieve their development goals by providing vision, direction, enthusiasm, priority, and access to required resources (Swink, 2000).
- Department and team management may enable IPD by, for example, enabling and supporting employees moving from functional responsibilities to NPD team responsibilities.
- Employees must support such teams in order for these teams to be effective and not simply exist on paper only.

Nijssen and Frambach (2000) found management involvement in the NPD process has a positive effect on the level of NPD tool adoption. This research study confirms the findings of Nijssen and Frambach (2000) and the importance of management support when attempting to infuse IPD in organizations.

Due to the similarity in the general goals of IPD practices (e.g., enable effective cross-functional communication and integration) it was expected that if one IPD practice is supported by members of the organization, then it is likely that these same members will support other IPD practices as well. The final research model highlights, by the strong total correlation (i.e., $r = 0.68$) between CFT support and CDP support, that this is indeed

the case. Therefore, by gaining support for the diffusion of one IPD practice, managers should have an easier time gaining support for the diffusion of other such practices.

Results of decomposing the correlation between CFT and CDP support show that approximately 31% of this correlation is explained by an innovative organizational climate and NPD complexity, with an innovative organizational climate playing a major role. With $r = 0.168$, innovative organizational climate explains 24.7% of the correlation between support for cross-functional NPD teams and concurrent product development processes.

In cases where an innovative organizational climate exists, managers can expect support for a wide variety of IPD practices. As a result, the number of options (i.e., practices) available to them to achieve IPD is greater. Conversely, and more of a concern to NPD managers, is that in a non-innovating climate, NPD managers will have a more difficult time implementing IPD regardless of the practices selected. This will occur as not only the practices they select are less likely to be supported, but other IPD practices, not considered, are less likely to be supported as well.

In addition to the quantitative analysis, the implications of member support for IPD diffusion are highlighted by manager's comments:

- I would like to see my organization adopt CE, but senior/exec. [management] is a problem. They don't know what it is; although they support NPD project teams, they are not proactive or involved? They are pre-occupied with other issues such as sales. I believe topics like [IPD] and quality are corporate issues that don't stand a chance of successful implementation unless there is a passionate and involved support/sponsorship at the very top of the organization.

- Poor leadership reflects poorly on the project which induces negative feelings about the task ahead and can result in minimal efforts at teamwork. The political support capital becomes diminished
- Concurrent engineering requires leader[ship] and commitment to using the process. With downsizing being everywhere and work loads increasing, it can be different to practice the discipline of communicating and working on a team.
- Concurrent engineering as you have described it has been in practice for over 20 years in a number of industries. The key to its use is the disciplined application by key mgmt leaders within a company. Although my organization is behind the times, as reflected in my answers, I clearly understand the need and benefits accordingly. I will also say my organization is mixed in terms of acceptance, some are embracing while others are not.
- This is a privately held company run by a family who are extremely wealthy and not dependant upon revenue from this co. There is no accountability or driving force to become efficient!
- The key to success is a high level program manager that forces decisions to be based on what makes the most business sense.
- Our family owned/managed company is going into the 3rd generation of family mgmt. We are going through a time of power struggles over who is in control. While team concepts are discussed, firm leadership to implement them is lacking.
- Easy to talk about and to agree to philosophically, but always hard to implement. Demanding conflicting priorities. Too many [projects] going on at [the] same time. Poor management follow-up. Hard to make it happen!
- Lack of planning by project managers or lack of commitment by supporting function managers. (i.e., response to the open-ended question addressing the major reasons why concurrent processes are not used on all NPD projects)

Based on these comments, it is evident that support for IPD influences its diffusion. In addition, and perhaps more important, these comments indicate reasons why member support for IPD may be lacking in some organizations. Examining these comments, reasons why IPD may not be supported in organizations include senior management's lack of understanding of IPD, lack of senior management commitment to using IPD, no business case for using IPD, poor management follow-up once IPD is implemented, low

priority of IPD in relationship to other organizational issues and initiatives (e.g., enterprise resource planning, supply chain management), negative feelings about the projects on which IPD are being used, poor NPD team leadership, too great a workload for employees if they are not 100% dedicated to the team. These variables were not considered in the research model, but must be addressed by NPD managers if support for IPD is going to occur in organizations.

These comments have very important implications to managers and researchers alike. The majority of the comments regarding IPD support are senior management type issues (e.g., priority of IPD, management leadership). This seems to highlight NPD managers' frustration with senior management when attempting to create support for IPD, emphasizing that senior management represents one of the largest obstacle or catalysts when creating support for IPD practices.

Although the research literature highlights that senior management plays a critical role in successful NPD (e.g., Mahajan & Wind, 1992, Swink, 2000), the importance of these comments is that they highlight specific actions that NPD managers can take to improve support for IPD. Based on the managerial comments, NPD managers can improve support for IPD by making senior management well aware of IPD and its benefits, ensuring excitement exists for the projects that are using IPD, championing IPD as a priority for the organization, ensuring a sound business case exists for the diffusion of IPD, and providing senior management with updates regarding IPD diffusion to ensure senior management follow-up.

Of course, as with an innovative organizational climate and NPD complexity, there are also issues that will influence support for IPD of which NPD managers may not be capable of extensively changing. Based on these same managerial comments, such issues include a lack of management leadership and too great a workload for team members that are not 100% dedicated to the NPD team.

These comments also have important research implications. A review of the research indicates that future research is required to identify factors that influence IPD support and ultimately IPD diffusion. These qualitative comments provide future researchers of IPD various managerial issues influencing IPD support. Given the emphasis of these comments on senior management issues, future research could focus on, for example, the major senior management issues or characteristics that create or stifle support for IPD in organizations.

8.4 Indirect Determinants of IPD Diffusion

In addition to factors that may directly influence the extent of IPD diffusion in organizations, managers must also be aware of factors that indirectly influence IPD, by directly influencing the support for such practices. These indirect factors are referred to as indirect determinants of IPD diffusion and include the complexity of the organizations NPD activities and an innovative organizational climate.

8.4.1 Innovative Organizational Climate

This research proposed that the climate of the organization would influence support for IPD in the organization. The reasoning presented was that IPD would be more supported in organizations that are open to new ideas and innovations in general. Such a climate is referred to as an innovative organizational climate.

It is apparent that the climate of the organization positively influences support for IPD in the organization, explaining approximately 16.5% of the variance for CFT support and 17.2% for CDP support. Therefore, one of the best early indications to managers of whether IPD will be supported by members of the organization is the climate of the organization. In an innovative climate, one that is open to new ideas and innovations, managers can expect increased support for IPD. One possible reason for this support is that a climate with the blurring of job boundaries and incremental information sharing, already contains much of the major goals of IPD. As a result, the use of IPD may require less disruptive organizational changes when compared to a low innovative climate, and thus will be met with less resistance by organizational members. The importance of an innovative climate is also supported qualitatively by various manager comments:

- The principles [of IPD] are rather simple; the organization culture changes required are very complex!
- The advantages of concurrent processes and cross-functional teams is understood by our company. However, the barriers to implementing this include resistance to change and departmental resistance to working openly with other departments.
- We went to cross-functional work teams approximately 2 years ago. At that time, it was a huge culture shock which we still have not surmounted.

- Concurrent Engineering in concept works ... In order to be successful, you must have good communications to ensure all issues are recognized and resolved before they become issues, not always easy to train. We keep trying to make it work, but our old habits are hard to change.
- We are a \$12,000,000 division vertically integrated in a \$100,000,000 company. We supply to sister companies and find they are slow to contact us when developing new products. Also we are poor at integrating input between both us and their own internal divisions. This is due to their history where depts. are treated more like silos.

It was also found that an innovative organizational climate directly influences the quality of communication between the functional disciplines involved in developing new products, explaining 17.8% of the variance. If an organization is open to new ideas and innovations, then it is expected that the functional disciplines directly involved in NPD will be more willing to work together on NPD projects.

This finding has major implications to NPD managers. How effective IPD practices are in improving performance not only depends on extensively diffusing IPD practices, but also the climate that already exists in the organization; of which the NPD manager is unlikely to be capable of extensively changing, again highlighted by the following manager comments:

- The organization culture changes required are very complex!
- At that time, it was a huge culture shock which we still have not surmounted.
- We keep trying to make it work, but our old habits are hard to change.

As a result, NPD managers must expect the benefits of IPD to be less in non-innovative climates versus innovating ones; highlighting that IPD may not work well in all organizations and that two organizations with the same level of IPD diffusion may experience completely different performance results due to climate differences.

8.4.2 NPD Complexity

New product development complexity is captured by assessing the major characteristics of the organization's NPD activities which contribute to task uncertainty. It was expected that the greater the complexity of the organization's NPD activities, the greater the need and support for IPD practices. Results of the data analysis indicate that this is the case. The complexity of the NPD activities undertaken by the organization does influence member support for IPD, however, not to the same extent as the climate of the organization. New Product Development complexity explains 8.9 % of the variance in CFT Support and 8.7 % in CDP Support. Managers can, therefore, expect increased support for IPD if the majority of the organization's NPD projects are considered to be complex.

Managerial comments qualitatively support the view that NPD complexity influences IPD support.

- Direct isolated use of non-concurrency [is appropriate] when risk is low, e.g. small revisions to established lines. Full applications of concurrency or 100% of projects regardless of scope are full hardy, it can't be supported by enough people or the same people over represent.
- Some projects are small and only require a small amount of input by production units. It is costly to organize meetings in these cases
- Due to many small incremental changes to products, the involvement of there functional disciplines in these projects is minimal, or can be accomplished by the design engineers without need of additional personnel.
- Average time from concept to implementation of product design is 3-5 months. This doesn't afford a great deal of opportunity to incorporate a high degree of concurrent dialogue. The products developed within the industry are generally well defined by the customer to the sales group. Very seldom is a product conceived and then marketed to the industry. There is in general a very high level of comprehensive knowledge of the industry within the engineering, sales, and supplier groups.

Summarizing this qualitative data, two major NPD characteristics influence IPD support, specifically the size (i.e., large versus small) and type (i.e., incremental versus radical) of NPD project. Based on these comments, if managers want to increase support for IPD, they should emphasize its usage on large complex projects, as the benefits of functional integration may be more obvious. It is also apparent that in cases where NPD projects are small and are incremental in nature, IPD may not be warranted; supporting an emerging view in the literature that IPD may not be appropriate on incremental type projects.

Organization size was not directly addressed by this study. The justification is that organization size represents a surrogate measure of many different organizational characteristics including, among other things, the number of functional departments, organizational structure, and expertise of employees (e.g., Nijssen & Frambach, 2000). It is therefore more appropriate to directly capture these characteristics. This research captured many of these characteristics in the NPD complexity and innovative organizational climate variables.

Reviewing managerial comments, it appears that organization size positively influences IPD diffusion:

- Our organization is relatively small and we specialize in design and [manufacture] of custom machinery. Although we use all of the techniques you describe on virtually all major projects it is done on a rather informal basis, without defined teams or procedure. This is possible because we are a small organization.
- We are really too small to formally adopt such terminology in our business 2 [engineers], 1 sales/marketing, 10 clerical and 50 in shop.

- Our company is small and our engineering team must, out of necessity, handle all aspects of the design to production sequence. Other [departments] are involved to facilitate the complete process. We don't use the buzz words concurrent engineering, that's just the way it is done.
- Our division is a small portion of a larger corporation. Currently we have approximately 80 employees at this site. Although product development is critical, many employees are performing dual roles. Design, develop, process engineering are all one person. There has always been the formal development process, but in our company we have an informal path as well.
- Our company is a small company (about 100 million annual sales). We have eleven corporate researchers/developers and therefore we by necessity have to work with production units to make production prototypes and marketing to sort out sales possibilities.
- Our plant is relatively small (150 people). Minimal layers of [management]. Technical director manages several of the functions.

Upon closer inspection of these comments however, it is apparent that organization size is indeed a surrogate measure of various organizational characterizes. Based on managerial comments, these characteristics include an increased use of informal procedures for developing products among smaller organizations and multiple roles of management and employees in smaller organizations.

In organizations where employees play multiple roles the use of IPD is likely to be less. If one person is the designer and manufacturing engineer, then there is no need for IPD as the major NPD activities are completed by one person. Based on these same comments, in organizations where informal processes are already in place, the diffusion of formal IPD practices are also likely to be lower; as the justification for such practices may be limited since the benefits of IPD are currently being achieved.

One major research issue that the qualitative data raises is that caution must be used when addressing organization size in IPD studies. As organization size is a surrogate measure of many different organizational characteristics, the researcher may be unsure of exactly what they are capturing. The qualitative data exemplifies this concern by showing that in some cases organization size is capturing the extent of multiple roles of managers and employees; while in other cases organization size is capturing the use of informal processes by the organization. Future IPD research should not focus on capturing organization size. Instead, future research should focus on identifying potential organizational characteristics that size captures, such as multiple roles of employees and informal processes, and incorporating these characteristics into research studies.

8.4.3 *NPD Strategy*

This research proposed that the NPD strategy of the organization would influence NPD performance. It was expected that in an organization where NPD is key to competitive success, there will be a greater need for successful NPD and thus greater support for integrated product development (e.g., Nijssen & Frambach, 2000; Rothwell, 1992). With NPD complexity influencing IPD support, one would also expect that the NPD strategy of the organization to also influence the support for IPD in the organization. An organization developing primarily new-to-the-world products should have greater support for IPD versus those organizations focused on incrementally improving existing products. However, results of the data analysis indicate that this is not the case. At face value, the NPD strategy of the organization does not influence support for integrated product development.

The major difficulty in capturing NPD strategy is that an organization is likely to be developing a combination of incremental innovations, major modifications, and new to the firm, country, or world products. Therefore, the NPD strategy of an organization cannot be easily placed into any one of these five categories. This research attempted to place NPD strategy on a continuum by identifying the percentage of products that fall into each category and then assigning a weight to each category.

One possible reason for a lack of a relationship between NPD strategy and IPD support is that the complexity of the organization's NPD projects may be a much better indication of the organization NPD activities, and thus overall strategy, versus attempting to categorizing the complexity of the organization's NPD activities into incremental innovations through to new-to-the-world projects.

One would expect NPD complexity to increase as organizations fall increasingly towards developing primarily new-to-the-world products. However, depending upon the past experiences and projects completed, technology available, employee turnover, and the skills of the people involved, a major modification to an existing project in one organization may be as complex as a new-to-the-country project in another organization. Therefore, the complexity of the NPD projects developed is perhaps a better overall indication of the organizational NPD activities, versus the type of strategy.

This finding should therefore not be strongly interpreted as the NPD strategy of the organization not influencing IPD support. This is best highlighted in Table 7.3, where the p -value for NPD strategy in the CDP support regression model is 0.057; very close to the critical p -value of 0.05. Rather, this finding better highlights that the measure of NPD strategy developed for this study may not strongly capture the NPD strategy of the organization. As a result, much more research is required to identify both uni-dimensional and multi-dimensional measures of NPD strategy so that robust and widely accepted means of capturing this important construct can be developed.

8.5 NPD Performance

Many researchers have proposed a relationship between IPD practices and NPD performance, citing significant reductions in NPD cycle time, product life-cycle costs, and engineering changes. Empirical research has also found relationships, albeit often conflicting, between IPD practices and NPD performance (e.g., Ettlie, 1993, 1995; Moffat, 1998). Qualitative data from this study also indicates that IPD diffusion will influence NPD performance, as presented below.

- Refinement of concurrent [engineering] and use of [cross-functional] teams has reduced product development timeline from 9 mons. to 30 days, NPD projects from 6/yr to 60+/yr.
- We began using concurrent eng. approx. 2 yrs ago to help increase speed to market. Results have been favourable in keeping costs within budget and [the] project on time.
- Concurrent engineering has been a strong functional tool to prevent major [costs] and loss through prevention of mis-stepping of a project development. The more eyes, the more seen.

- Works well to facilitate meeting time lines [and] goals by minimizing errors. People when involved in a project, feel worthy and will tend to support it and help make it successful. Provides cross-checks to minimize possibility of interference between departments. Gives all a voice in it to prevent project from being developed in a way that makes it difficult or costly for some functional disciplines to perform the required procedures.
- Projects run smoother, faster products to market, quicker feedback from manufacturing back to design, all parties involved understand the overall scope of the project.
- Company used standard throw it over the wall design to 5 years ago. Since using concurrent [engineering] all products were developed on time and on budget.
- Our philosophy for the past decade has been design for [manufacture]. This recognizes that any [department] that is involved with the process of providing a product to the end user is involved with the decision making process concerning the design, [manufacture], and delivery of the product. We have graduated from the school of hard knocks and learned that we get a better (more reliable, high performance) product quicker and more cost effectively if we employ a concurrent engineering process.
- Our first benchmark of concurrent engineering resulted in 30% fewer engineering changes during initial production introduction, capital budgets were less than planned and installation quality goals exceeded targets.

Based on the qualitative data, a number of performance gains can be achieved by using IPD, including reductions in product development time, costs, and engineering changes, and team member commitment to the project. These performance gains are identical to those commonly cited in the conceptual research literature. Examining the qualitative data and the conceptual research literature, one would expect a significant direct relationship between IPD diffusion and NPD performance. Results of the quantitative data analysis, however, found a very weak relationship (i.e., statistical significance but no practical significance and a low r^2) between IPD diffusion and NPD performance. This relationship was rejected in favor of a better model.

This finding provides some support for Moffat (1998), who found that some IPD practices, such as cross-functional NPD teams, do not directly influence NPD performance. On the other hand, Moffat (1998) also found that concurrent product development processes directly influence NPD performance, which this research does not support.

One possible reason why a direct relationship between IPD diffusion and NPD performance is qualitatively, but not quantitatively, supported is that a mediating variable may influence the IPD diffusion → NPD performance relationship. Such a variable may be hard to detect in the qualitative comments and, if not controlled for, could explain the inconsistent empirical finding of studies examining IPD practices and NPD performance. Based on the quantitative data analysis, a mediating variable has been identified, specifically communication quality. From the quantitative analysis, it is apparent that IPD diffusion influences communication quality which in turn influences NPD performance.

8.6 Communication Quality

Communication quality is a new construct developed by modifying the teamwork quality measurements developed by Hoegl and Gemuenden (2001). Communication quality is the extent that IPD has improved the integration (i.e., the extent that functional disciplines involved in NPD work together and towards the same common goals) and communication (i.e., how well the various functional disciplines communicate with one another when developing new products) between the functional disciplines involved in NPD activities.

As with NPD performance, this research expected a direct relationship between IPD diffusion and communication quality. Results of the data analysis indicates that this is the case. In addition, it was found that communication quality directly and strongly influences NPD performance. Therefore, simply using IPD practices is not enough to improve NPD performance. Instead, and as suggested by Gerwin and Barrowman (2002), in addition to how often they are used, one must also consider the quality of IPD practices.

The role of communication quality in predicting NPD performance is fairly large, with 26.9% of the variance in NPD performance explained. This fairly large percentage highlights that researchers and managers alike must realize that in addition to simply using an IPD practice, it must also be used well. To researchers, the major implication of this finding is that past studies of IPD may have improperly measured the performance of IPD practices by assuming that such practices directly influence NPD performance. Therefore, researchers may conclude that a practice is not effective (i.e., low NPD performance), when instead it may have been (i.e., high communication quality), with other moderating variables leading to poor NPD performance.

To managers, this finding highlights that having IPD practices exist on paper only will do very little to improve NPD performance. As a result, IPD practices must not be consider a one time activity or “flavour of the month”, where managers implement them and then forget about them. Instead, IPD practices must be constantly monitored to ensure that they are indeed increasing the communication and integration of the functional

disciplines involved in developing new products, which will in turn, ultimately lead to improvements in NPD performance. Integrated product development practices which do little to improve communication quality will not lead to improvements in NPD performance.

Many factors may influence how well an IPD practice is used. This research captures two such factors. The first and most important is an innovative organizational climate, explaining 17.8% of the variance in communication quality. As previously discussed (i.e., Section 8.4.1), one would expect that IPD practices will be more effective, and therefore produce better results, in a climate open to new ideas and innovations.

The second factor is IPD diffusion. Cross-functional NPD team diffusion explains 15.1% of the variance in communication quality, while CDP diffusion explains 7.8%. The large gap between these two IPD practices highlights that cross-functional NPD teams are better at improving the quality of communication and interaction between the functional disciplines involved in NPD versus concurrent product development processes. One possible reason is differences in the team structure used for these practices. With a concurrent product development process, only certain NPD activities may be overlapped and thus the functional disciplines involved may be less (e.g., design and manufacturing only) versus a cross-functional NPD team which may contain representation from a wider range of functional disciplines. Future research is required to identify other major differences between the teams used to carry out these IPD practices and their influence on communication quality.

The direct relationship between IPD diffusion and communication quality seems to indicate a learning effect. Organizational learning is the “set of actions (knowledge acquisition, information distribution, information interpretation, and organizational memory) within the organization that intentionally and unintentionally influence positive organizational change” (Templeton, Lewis, & Snyder, 2003, p. 189). Sorenson (2003) gives an example of a learning effect in a manufacturing context:

By incorporating knowledge from their experience, firms build libraries of effective routines that allow them to reduce the cost of producing a particular good or service; put simply, firms get better at making things as they gain experience producing them – they learn by doing. (p. 446)

Examining the quantitative data, it appears that a learning effect exists between IPD diffusion and communication quality:

- We began using concurrent [engineering] approx. 2 yrs ago to help increase speed to market. Results have been favorable in keeping costs within budget and project on time. These programs were established to combat poor develop coordination. Marketing requirements were inconsistent and [manufacturing] had poor acceptance due to design projects being completed without interaction from other disciplines. This process is still evolving as we continue to learn how to work smarter.
- My firm is only 40 years old. It started concurrent when the founders (1 sales/marketing, 1 engineering/[manufacturing]) worked together. As they added their children, the additional people stayed attached with one another and relied on each others expertise to ensure success. The rare failures to concurrently engineer come when new smarter people come aboard not recognizing interdependence.

Based on learning theory and these managerial comments, it is expected that overtime the organization, by extensively diffusing IPD practices, will gain experience on how to use these practices effectively, thereby influencing organizational change; which in the case of this relationship is improving the communication and integration of the functional disciplines involved in product development. Issues that will need to be addressed as IPD is diffused to enable the organization to build “effective routines” include the

optimal mix of functional representation (i.e., who should be represented and how often during the project) and activity overlap (i.e., what NPD activities should and should not be overlapped, should these activities be partially or completely overlapped).

8.7 Interaction Effect of IPD Practices

Gerwin and Barrowman (2002) make a number of recommendations for future studies of integrated product development; one of which is to examine the interaction effect of IPD practices. This research addresses this important issue by examining the interaction effect of CFT and CDP diffusion (i.e., CFT diffusion $\times$ CDP diffusion) on IPD performance.

In exploring the relationship between this interaction effect and NPD performance, it was found that the interaction effect explains only 5.9% of the variance in NPD performance. This variance explained is only slightly above the summed independent contributions of CFT and CDP diffusion at 5.4%. It is therefore concluded that the interaction effect of CFT and CDP diffusion does not significantly improve NPD performance when compared to the sum of the independent contributions of these variables.

As with the independent contributions, this study examined the influence of the interaction effect on communication quality. In examining the relationship between the interaction effect and communication quality, the interaction variable explains only 19.9% of the variance in communication quality which is lower than the sum of the independent contributions at 22.9%. It is thus concluded that the “‘whole’ integration effect of the [IPD] approach is dramatically greater than the ‘sum’ of the independent

contributions” (Moffat 1998, p. 61) is not supported in terms of improving NPD performance or communication quality.

To researchers, this finding allows for more simple research models to be developed, specifically ones with no multiplicative effects between IPD practices. To managers, this finding highlights that a synergistic relationship between IPD practices and communication quality or NPD performance does not exist. As a result, managers should not expect communication quality improvements significantly beyond the individual contribution of that practice.

CHAPTER IX

CONCLUSION

9.1 In Summary

Integrated product development has been praised in both the academic literature and popular press as a means of improving the success of NPD projects. This study found many of the commonly cited benefits of IPD, including reductions in development cost, cycle time, and engineering changes. This study, more importantly, also found many problems with IPD, including functional disciplines, such as manufacturing, not being measured on their NPD involvement or performance, team members using IPD for their own personal advantage, people brought in from other functional disciplines not prepared for the failure associated with NPD, and employee difficulty in balancing their commitment to the NPD team and functional discipline.

Despite the many problems associated with IPD in organizations, its diffusion remains quite high. The use of cross-functional NPD teams in organizations is slightly increasing, with 87% of the responding organizations using this IPD practice. Concurrent product development processes slightly trails the diffusion of cross-functional NPD teams, with 77% of responding organizations using the former practice. Approximately 70% of responding organizations used both practices when developing new products, while 24% used both practices 100% of the time when developing new products. Although these practices are commonly used, they are likely to be different levels of diffusion in the organization.

The initial model developed for this study proposed that IPD diffusion would influence both communication quality and NPD performance. This IPD diffusion would be directly influenced by IPD practice diffusion difficulty and support and indirectly influenced by the NPD strategy, NPD complexity, and organizational climate. Results of surveying 269 NPD managers resulted in a final model that deviates from this initial research model.

Of the IPD practice diffusion difficulty manifest variables only CFT complexity influences IPD diffusion. Based on the qualitative data, it appears that practice diffusion difficulty is not a major factor in deciding whether or not to use IPD, except under conditions of high cost, risk, or complexity.

This study found that obtaining support for IPD is one of the most important steps that can be taken to extensively diffuse IPD within an organization. More importantly, this research also highlights NPD managers' frustration with senior managers when implementing IPD and proposes steps NPD managers can take to improve support for IPD practices. Such steps include making senior management well aware of IPD and its benefits, ensuring excitement exists for the projects that are using IPD, championing IPD as a priority for the organization, ensuring a sound business case exists for the use of IPD in the organization, and providing senior management with updates regarding IPD diffusion to ensure senior management follow-up.

This study also found that an innovative organizational climate and the complexity of the organization's NPD activities also influence support for IPD practices. Combining these quantitative findings with managerial comments, there are a number of issues or items that will influence support for IPD of which NPD managers may not be capable of extensively changing, including the climate of the organization, complexity of product development activities, a lack of management leadership, and too great a workload for team members that are not 100% dedicated to the NPD team.

Organization size was not directly addressed by this study. The justification was that organization size represents a surrogate measure of many different organizational characteristics, many of which are captured by this study. As organization size is a surrogate measure of many different organizational characteristics, the researcher may be unsure of exactly what they are capturing. The qualitative data shows, for example, that in some cases organization size is capturing the extent of multiple roles of managers and employees; while in other cases organization size is capturing the use of informal processes by the organization.

Although proposed by the research model, the NPD strategy does not influence IPD support or IPD diffusion. However, interpreting this finding should be approached with caution, as it may simply be a problem with the way the NPD strategy was conceptualized for this study.

It was expected that IPD diffusion would directly influence NPD performance. The qualitative data shows that such a significant direct relationship does exist. However, the quantitative data found a very weak relationship (i.e., statistical significance but no practical significance and a low r^2) between NPD practices and NPD performance. This research instead found a new variable, communication quality, mediates the NPD practice-performance relationship, helping to explain why a significant direct relationship between IPD diffusion and NPD performance is qualitatively, but not quantitatively, supported and the inconsistent empirical finding of studies examining IPD practices and NPD performance. More specifically, an innovative organizational climate and IPD diffusion influences communication quality which, in turn, influences NPD performance. This relationship emphasizes a learning effect when diffusing IPD practices. The more IPD is diffused, the better the organization will become at using IPD, resulting in NPD performance improvements.

The research literature recommends that studies of IPD consider the interaction effect between practices. Following this recommendation, the interaction effect of CFT and CDP diffusion on communication quality and NPD performance was examined. This study found that this interaction effect significantly influences communication quality and marginally influences NPD performance. However, the former interaction effect was lower than the sum of the independent contributions of CFT and CDP diffusion, thus deconstructing the suggestion by researchers that the whole integration effect of IPD practices is much greater than the sum of the independent contributions of such practices.

This completed research study has a number of important implications to both researchers and NPD managers, which are discussed in detail throughout Chapter Eight. In addition to these implications, this research study addresses some important gaps in the current research literature. This completed research study makes a significant and original contribution to knowledge in the field of operations management in a number of ways, including:

- Answering the call of researchers by examining the diffusion of IPD in significant detail.
- Showing that IPD diffusion only weakly influences NPD performance.
- Identifying a new mediating variable, specifically communication quality, which significantly influences NPD performance.
- Confirming that a synergist effect does not exist between cross-functional NPD teams and concurrent product development processes.
- Highlighting the problems of using organization size in IPD studies.
- Illustrating the difficulty and need to better conceptualize NPD strategy.
- Identifying the major sources for a lack of support for IPD, including those which can and cannot be changed by NPD managers.
- Showing the strong role that an innovating organizational climate plays in IPD diffusion.
- Highlighting common and less common problems of IPD diffusion.
- Presenting the current level of IPD diffusion in organizations.

9.2 Limitations and Future Research

To understand the diffusion of IPD practices in organizations, both the extent and determinants of IPD diffusion for each practice must be captured. As a result, the major limitation of this research is that only two IPD practices have been selected for examination in order to prevent the risks and problems associated with developing a very long questionnaire. Therefore, the research model developed is based on examining only two administrative IPD practices, specifically cross-functional NPD teams and concurrent product development processes. Applying this research model to other administrative IPD practices must be approached with caution. Future research should focus on examining other administrative IPD practices that are commonly used to achieve IPD, such as physically co-located NPD teams, in order to test the generalizability of the research model to other administrative IPD practices.

As stated in Chapter Two, the factors influencing the diffusion of administrative innovations differ from technological innovations. As a result, the research model, at this time, should not be applied to technological IPD practices such as common information technologies (e.g., common databases, CAD/CAM systems). Future research should therefore focus on testing and further developing the research model by considering technological innovations and how the determinants of diffusion of such practices differ from administrative ones.

This research addresses organizational-level determinants only. Although, the variables selected explain a significant portion of the variance in the dependent variables, a major limitation of this research is that potential NPD team (e.g., team autonomy) and environmental (e.g., IPD usage by competitors, suppliers) factors have not been considered. Future research should focus on addressing NPD team and environmental factors in order to develop as holistic a model of IPD diffusion as possible. Of the organizational-level determinants explored by this study, future research is needed to better capture the NPD strategy construct.

Examining the final model presented in Figure 7.13, it is plausible that feedback loops may exist between various components of the research model. For example, it is plausible that CFT diffusion influences CFT support. If such teams are successfully used on a few projects, then it may increase support for cross-functional NPD teams and thus further diffusion. Likewise, it is plausible that communication quality influences diffusion. If there is an increase in the quality of communication between the functional disciplines involved in NPD as a result of using cross-functional NPD teams and concurrent product development processes, then it is possible that such disciplines would be more willing to use these IPD practices on NPD projects, thus influencing their diffusion. Unfortunately, one major limitation of path analysis is that feedback loops such as these cannot be tested. Further research should attempt to test these relationships using techniques such as interviews and case studies.

Examining Figure 7.5, it is apparent that the residuals for CDP Diffusion are only, at best, marginally normally distributed. Transforming the data (e.g., squaring the data, log transformation) did not improve the distribution of the residuals. As a result, the relationship between CDP Support and CDP Diffusion must be approached with caution.

Gerwin and Barrowman (2002) found that cross-functional NPD teams do not reduce goal failure, suggesting that managers may set stricter goals in return for committing the resources required to diffuse cross-functional NPD teams. One managerial comment provides some support for this premise:

- Our first benchmark of concurrent engineering resulted in 30% fewer engineering changes during initial production introduction, capital budgets were less than planned and installation quality goals exceeded targets. This set a precedent to where we are today in that people are expecting more than the process is capable of delivering.

Based on Gerwin and Barrowman's (2002) suggestion and the above comment, future research is required on how IPD diffusion influences managerial and employee expectations of product development activities. For example, additional research is needed to determine if and what managerial expectations increase as a result of using IPD practices and analyze the capability of these practices to deliver such expectations.

This research focuses on organizations operating in a specific set of industries and geographic area and ranging in size of between 50 and 1000 employees. As a result, this study may have limited generalizability to companies that are not represented by North American Industry Classification System (NAICS) Codes 333 (i.e., Machinery Manufacturing), 334 (i.e., Computer and Electronic Product Manufacturing), 335 (i.e.,

Electrical Equipment, Appliance, and Component Manufacturing), and 336 (i.e., Transportation Equipment Manufacturing) manufacturers, operate outside of Canada and the United States, or are very small (i.e., < 50 employees) or large (i.e., > 1000 employees). Future research should focus on expanding this research in terms of both industrial and demographic scope.

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APPENDICES

Appendix 1

Common Practices for Achieving IPD

Group/Practice	Definition	Used or suggested by
Process Focused		
Top Management Support	Active and visible support for IPD from managers	Liker, Collins, & Hull, 1999; Swink, 2000;
Low Management Hierarchy	Low number of layers before a common design/manufacturing manager	Liker, Collins, & Hull, 1999; Rusinko, 1999;
Project specification	Clearly documenting the customer requirements.	Ainscough & Yazdani, 2000
Project planning	Planning on which information to release to downstream players	Ainscough & Yazdani, 2000
Formal NPD process	A "formal blueprint, roadmap, template or thought process for driving a new product project from the idea stage through to market launch and beyond" (Cooper, 1994).	Poolton & Barclay, 1998
Formal CE Assessment Tools	Tools to access your company's readiness for concurrent engineering (e.g., RACE – Readiness Assessment for Concurrent Engineering, Mentor Graphics Corporation CE Assessment Tool).	Barclay & Dann, 2000
Formal Methods		
Benchmarking	"Measuring your performance against that of best-in-class companies, to determining how the best-in-class companies achieve those performance levels, and using the information as a basis for your own company's targets, strategies, and implementation" (Pryor, 1989).	Ettlie, 1995
Quality Function Deployment (QFD)	"A method designed to help the NPD-project team to identify and interpret the needs and wants of customers. The aim is to establish the importance of product attributes and transform them into technical requirements" (Nijssen and Frambach, 2000).	Ainscough & Yazdani, 2000; Nijssen & Frambach, 2000; Poolton & Barclay, 1998; Trygg, 1993
Design for Manufacture	"The systematic consideration of manufacturing issues in the design and development process, facilitating the fabrication of the product's components and their assembly into the overall product" (PDMA, 2002).	Ainscough & Yazdani, 2000; Ettlie, 1995; Poolton & Barclay, 1998; Trygg, 1993
Brainstorming	"A systematic creative group session in which barriers to creative thinking are removed to stimulate the production of new ideas through association" (Nijssen and Frambach, 2000).	Nijssen & Frambach, 2000;
Delphi Method	A multi-survey consisting of several sequential rounds in which a number of experts are asked to give their opinion and vision on developments. Through feedback one general vision is established" (Nijssen and Frambach, 2000).	Nijssen & Frambach, 2000;

Rapid Prototyping	Any of a variety of processes that avoid tooling time in producing prototypes or prototype parts and therefore allow (generally non-functioning) prototypes to be produced within hours or days rather than weeks. These prototypes are frequently used to test quickly the product product's technical feasibility or consumer interest (PDMA, 2002)	Ainscough & Yazdani, 2000;
People Focused		
Physical collocation	"Physical proximity of various individuals, teams, functional disciplines, and organizational sub-units involved in the development of particular product or process" (Rafi, 1995)	Abdalla, 1999; Liker, Collins, & Hull, 1999; Poolton & Barclay, 1998; Rusinko, 1999
Virtual collocation	The use of information technologies to simulate face-to-face communication and allowing for the sharing of information.	Hague & Taleb-Bendiab, 1998; Swink, Sandvig, & Mabert, 1996
Cross- functional teams	A new product development team comprised suppliers, customers, and members from various business functions, such as manufacturing, design, and marketing.	Ganapathy & Goh, 1997; Liker, Collins, & Hull, 1999; Poolton & Barclay, 1998; Swink, Sandvig, & Mabert, 1996; Trygg, 1993
Early Customer Involvement	The participation of the customer in the front-end phases of the new product development process	Baake, Stratiil, & Haussmann, 1999; Ganapathy & Goh, 1997; Liker, Collins, & Hull, 1999; Poolton & Barclay, 1998; Trygg, 1993
Early Supplier Involvement	The participation of the supplier in the front-end phases of the new product development process.	Baake, Stratiil, & Haussmann, 1999; Calabrese, 1999; Fleischer & Liker, 1997; Ganapathy & Goh, 1997; Liker, Collins, & Hull, 1999; Poolton and Barclay, 1998 Trygg, 1993
Concurrent/ Concurrent Process	Overlapping various NPD activities	Gerwin & Barrowman, 2002; Gerwin 2002; Moffat, 1998
Supplier-Base Reduction	A reduction in the number of suppliers need to produce the new product.	Trygg, 1993
Joint Design Reviews	Design, manufacturing, and other key NPD players review product designs as a group.	Trygg, 1993
Design/ Manufacturing Job Rotation	Having design people work in the manufacturing departments and vice versa.	Hauptman & Hirji, 1999; Liker, Collins, & Hull, 1999; Rusinko, 1999; Trygg, 1993
Group-Based Evaluation	Evaluating group performance instead of individual performance.	Rusinko, 1999
Group Rewards	Rewarding the entire NPD team for successfully developing a new product.	Hauptman & Hirji, 1999; Liker, Collins, & Hull, 1999; Poolton & Barclay, 1998

Group Recognition	Recognizing the actions of the entire NPD team for successfully developing a new product.	Poolton & Barclay, 1998
Team training in CE	Training programs on the key philosophies, benefits, and practices of concurrent engineering.	Abdalla, 1999; Liker, Collins, & Hull, 1999
Informal Face-to-Face Communication		Liker, Collins, & Hull, 1999
Formal Face-to-Face Communication		Liker, Collins, & Hull, 1999
IT Tools		
Common Databases	Data from the various functions are stored in a single database.	Trygg, 1993
Simulation tools	The use of software to simulate the product and manufacturing processes to develop and refine both product and process designs.	Poolton & Barclay, 1996; Prasad, 1996
Common CAD/CAM Systems	Manufacturing and design use the same CAD/CAM systems. This enables design to consider manufacturing issues when developing new products.	Ainscough & Yazdani, 2000; Liker, Collins, & Hull, 1999; Poolton & Barclay, 1998; Prasad, 1998; Trygg, 1993

Appendix 2

Partial List of Factors Influencing the Diffusion of Innovations

Perceived Innovation Characteristics	
Adaptability	The ability to refine, elaborate, and modify an innovation according to the needs and objectives of the implementers.
Architectural Impact	The extent to which an innovation impacts the usefulness of existing architectural versus component knowledge of the firm.
Centrality	The degree to which the innovation concerns the major day-to-day work of the organization and involves activities critical to organizational performance.
Compatibility	The degree to which an innovation is consistent with the existing values, past experiences, and needs of potential adopters.
Complexity	The extent to which an innovation is perceived as relatively difficult to understand and use.
Cost	The extent of initial financial investment and on going expenses.
Divisibility	The degree to which the innovation is a tight package of interlined parts as opposed to being a loose composite of independent parts that could be adopted separately.
Duration	The period of time to which the change is applicable and is intended to persist.
Magnitude	The degree of displacement of existing organizational states (e.g., structural arrangements, personnel, and financial resources) that the innovation implies.
Obseverability	The extent to which the results of an innovation are visible to others.
Organizational Focus	The aspect of the organization to which the innovation is most relevant.
Pervasiveness	The proportion of total behaviours occurring within an organization that are expected to be affected by the innovation; pervasiveness is a function of the number of how many organizational members are expected to change their behaviours due to the innovation and how much of the time these involved people will behaving in new ways.
Physical Properties	Classification on this dimension differentiates material or physical object innovations from social, programmatic, or process innovations.
Radicalness	The extent to which the innovation represents technological changes and thus implies new behaviours for organizational subsystems or members.
Relative Advantage	The extent to which an innovation is perceived as being better than the idea it supercedes.
Risk	The level of risk and liability to which the adopting organization is exposed.
Status	The extent to which an innovation is adopted in the quest of prestige rather than organizational profit or effectiveness.
Uncertainty	Knowledge concerning the link between the innovation's inputs, processes, and outcomes.
Supplier Marketing Efforts	
Targeting	Targeting the innovation towards selected potential adopters
Communication	Communication to create awareness of the innovation
Risk Reduction	Reducing the risk of adopting the innovation, including implementation, financial, and operation risk.
Social Network	
Interconnectedness / network participation	The interaction in terms of frequency and richness between members in a social network.

Environmental Influences	
Network externalities	Number of other interrelated organizations in their market environment that has adopted the innovation.
Competitive Pressures	Strategic importance of the innovation and its potential implications for the effectiveness and efficiency of the firm's activities.
Adopter Characteristics	
Size	Size of the organization
Structure	Structure of the organization. For example, formalized and centralized versus decentralized and flexible.
Organizational innovativeness or strategic posture	Degree to which the organization is receptive to new ideas.
Organizational Facilitators	
Training	Training and education on the innovation
Social Persuasion	Methods to persuade an individual to adopt the innovation. Examples include rewards, incentives and control structures
Organizational support	Technical support for the innovation
Adopter Personal Characteristics	
Demographics	Demographic characteristics such as age, gender, and education.
Innovation experience	Prior use of a particular or similar innovation.
Adopter's Attitude Towards Innovation	
Beliefs	Perceived beliefs towards the innovation (e.g., ease of use, perceived usefulness)
Affects	Perceived potential affect of the innovation on the adopter.
Personal Innovativeness	
Personal Innovativeness	Tendency of a person to accept an innovation within a product class, independently of the communicated experiences of others.
Social Usage	
Network externalities	Number of other interrelated organizations in their market environment that has adopted the innovation.
Peer usage	The acceptance of the innovation an individual's peers, such as colleagues, superiors and customers.

Appendix 3

NPD Performance Measurements

Classification	Measurements
Customer-Acceptance Measures	Customer acceptance Customer satisfaction level Customer retention rate % of sales exported Purchase intent rate prior to market introduction Customer count, number of customers Taken off market Length of product life Price/value as measured by the customer Relative sales level Purchase repeat rate Importance of the product to the retailer Return rate from the field or customers Met revenue goals Revenue growth Sales force acceptance Met minimum revenue levels by year 5 Variance of sales from plan Market position; industry success rate (ranking in market, i.e., #1) Met market share goals Year 1 market share Purchase sales rate in test market Met sales volume goal (units not revenue)
Measures of Financial Performance	Break-even time after release Break-even time from start of the project Attains margin goals Attains profitability goals Relative profits Return factor Internal rate of return or return on investment

Product-Level Measurements	<p> Ease of automating the production process Competitive reaction Provides a sustainable competitive advantage Meets cost goals Cost of developing the product Development efficiency Measure of failure – first disappointment during the development Ease of manufacture Launched on budget Level of innovation achieved Launched on time Technical performance of the product, performance to specifications Relative product performance Probably of success Development project progress versus milestones Met quality guidelines Speed to market Management's subjective assessment of success Ability to accrue political support within the firm Team satisfaction Product received an award denoting technical excellence Technical success of the project Impact on sales of other products; % cannibalization Product yield rate through the manufacturing process </p>
Firm-based Measurements	<p> Can be line-extended – Leads to future opportunities Strategic fit with business Hit a window of opportunity Number of new products % of products with high profits % of products with patent protection % of profits provided by products less than 5 years old % of sales provided by products less than 5 years old % of sales under patent protection PR value; amount of free advertising created by the product Success/failure rate of new products </p>
Program Measures	<p> Program exceeds company objectives Impact of the new product program on corporate performance Return on investment for the new product development process Overall success of the product development program New product program profitability New product program sales Subjective importance of the new product program </p>

Appendix 4

NAICS Definitions

333 Machinery Manufacturing

Industries in the Machinery Manufacturing subsector create end products that apply mechanical force, for example, the application of gears and levers, to perform work. Some important processes for the manufacture of machinery are forging, stamping, bending, forming, and machining that are used to shape individual pieces of metal. Processes, such as welding and assembling are used to join separate parts together. Although these processes are similar to those used in metal fabricating establishments, machinery manufacturing is different because it typically employs multiple metal forming processes in manufacturing the various parts of the machine. Moreover, complex assembly operations are an inherent part of the production process.

In general, design considerations are very important in machinery production. Establishments specialize in making machinery designed for particular applications. Thus, design is considered to be part of the production process for the purpose of implementing NAICS. The NAICS structure reflects this by defining industries and industry groups that make machinery for different applications. A broad distinction exists between machinery that is generally used in a variety of industrial applications (i.e., general purpose machinery) and machinery that is designed to be used in a particular industry (i.e., special purpose machinery). Three industry groups consist of special purpose machinery--Agricultural, Construction, and Mining Machinery Manufacturing; Industrial Machinery Manufacturing; and Commercial and Service Industry Machinery Manufacturing. The other industry groups make general-purpose machinery: Ventilation, Heating, Air Conditioning, and Commercial Refrigeration Equipment Manufacturing; Metalworking Machinery Manufacturing; Engine, Turbine, and Power Transmission Equipment Manufacturing; and Other General Purpose Machinery Manufacturing.

334 Computer and Electronic Product Manufacturing

Industries in the Computer and Electronic Product Manufacturing subsector group establishments that manufacture computers, computer peripherals, communications equipment, and similar electronic products, and establishments that manufacture components for such products. The Computer and Electronic Product Manufacturing industries have been combined in the hierarchy of NAICS because of the economic significance they have attained. Their rapid growth suggests that they will become even more important to the economies of all three North American countries in the future, and in addition their manufacturing processes are fundamentally different from the manufacturing processes of other machinery and equipment.

The design and use of integrated circuits and the application of highly specialized miniaturization technologies are common elements in the production technologies of the computer and electronic subsector. Convergence of technology motivates this NAICS subsector. Digitalization of sound recording, for example, causes both the medium (the compact disc) and the equipment to resemble the technologies for recording, storing, transmitting, and manipulating data. Communications technology and equipment have been converging with computer technology. When technologically-related components are in the same sector, it makes it easier to adjust the classification for future changes, without needing to redefine its basic structure. The creation of the Computer and Electronic Product Manufacturing subsector will assist in delineating new and emerging industries because the activities that will serve as the probable sources of new industries, such as computer manufacturing and communications equipment manufacturing, or computers and audio equipment are brought together. As new activities emerge, they are less likely therefore, to cross the subsector boundaries of the classification.

335 Electrical Equipment, Appliance, and Component Manufacturing

Industries in the Electrical Equipment, Appliance, and Component Manufacturing subsector manufacture products that generate, distribute and use electrical power. Electric Lighting Equipment Manufacturing establishments produce electric lamp bulbs, lighting fixtures, and parts. Household Appliance Manufacturing establishments make both small and major electrical appliances and parts. Electrical Equipment Manufacturing establishments make goods, such as electric motors, generators, transformers, and switchgear apparatus. Other Electrical Equipment and Component Manufacturing establishments make devices for storing electrical power (e.g., batteries), for transmitting electricity (e.g., insulated wire), and wiring devices (e.g., electrical outlets, fuse boxes, and light switches).

336 Transportation Equipment Manufacturing

Industries in the Transportation Equipment Manufacturing subsector produce equipment for transporting people and goods. Transportation equipment is a type of machinery. An entire subsector is devoted to this activity because of the significance of its economic size in all three North American countries.

Establishments in this subsector utilize production processes similar to those of other machinery manufacturing establishments - bending, forming, welding, machining, and assembling metal or plastic parts into components and finished products. However, the assembly of components and subassemblies and their further assembly into finished vehicles tends to be a more common production process in this subsector than in the Machinery Manufacturing subsector.

NAICS has industry groups for the manufacture of equipment for each mode of transport - road, rail, air and water. Parts for motor vehicles warrant a separate industry group because of their importance and because parts manufacture requires less assembly, and the establishments that manufacture only parts are not as vertically integrated as those that make complete vehicles.

Land use motor vehicle equipment not designed for highway operation (e.g., agricultural equipment, construction equipment, and materials handling equipment) is classified in the appropriate NAICS subsector based on the type and use of the equipment.

(NAICS, 2003)

Appendix 5
Research Cover Letter

<Eric Sprott School of Business Letterhead>

Dear <name>,

My name is Todd Boyle. I am a Ph.D. Candidate at Carleton University, Ottawa, Canada. I am currently working on my thesis research, which examines the use of concurrent engineering in North American manufacturing organizations. Concurrent engineering is an approach for improving new product development (NPD) performance where major NPD activities, such as product design and manufacturing process development, occur concurrently in an integrated fashion using a cross-functional team, rather than sequentially by separate functional disciplines.

The specific questions my Ph.D. thesis explores are: i) *why do some manufacturing organizations use concurrent engineering on every new product development project, while others use concurrent engineering on only a few key projects or not at all?* and ii) *what is the relationship between how manufacturing organizations use concurrent engineering and the new product development performance they obtain?*

This letter is to kindly request you to please participate in this study by **completing the enclosed questionnaire and returning it in the provided self-addressed stamped return envelope**. I do understand that your time is very valuable. However, by taking 10 minutes to complete this questionnaire **you will directly and significantly** enhance my ability to complete my Ph.D. thesis, for which I would be very grateful. As a way of saying thank you for assisting me with this research project, you will receive a copy of the research findings summarizing how organizations such as your own are using concurrent engineering and the benefits they are obtaining.

Even if your organization is not using concurrent engineering, I would ask you to still please complete the enclosed questionnaire, as reasons for not using concurrent engineering are as important as the reasons for using it.

Results of individual questionnaires are confidential and will not be disclosed to any outside parties. Anonymity will be ensured by assigning numbers to individual questionnaires and combining the results of individual questionnaires when reporting the research findings.

Thank you for your time and input.

<Signature>

Todd A. Boyle
Ph.D. Candidate

Appendix 6
Initial Questionnaire

Survey Number: _____

Survey of Concurrent Engineering

Thank you for completing this questionnaire.

Your input is very much appreciated.

Results of individual questionnaires are confidential and will not be disclosed to any outside parties. Anonymity will be ensured by assigning numbers to individual questionnaires and combining the results of individual questionnaires when reporting the research findings.

1. Please indicate the extent that the following describes your organization:

	Not at all			Moderately			Extremely			Unable to rate
It incorporates values of openness in decision making	1	2	3	4	5	6	7	8	9	☐
It incorporates values of collaboration	1	2	3	4	5	6	7	8	9	☐
It is receptive to change	1	2	3	4	5	6	7	8	9	☐
It is risk taking	1	2	3	4	5	6	7	8	9	☐
It is bureaucratic	1	2	3	4	5	6	7	8	9	☐

2. Thinking of the products your organization has developed in the past two years, please indicate the extent that the following success criteria are generally met:

In General ...

	Is never met					Is always met					Unable to rate
Market share (%)	1	2	3	4	5	6	7	8	9		☐
Market position	1	2	3	4	5	6	7	8	9		☐
Return on investment	1	2	3	4	5	6	7	8	9		☐
Customer satisfaction	1	2	3	4	5	6	7	8	9		☐
Break-even time	1	2	3	4	5	6	7	8	9		☐
Profit margin	1	2	3	4	5	6	7	8	9		☐
Sales target	1	2	3	4	5	6	7	8	9		☐
Product performance vs. specification	1	2	3	4	5	6	7	8	9		☐
Quality standards	1	2	3	4	5	6	7	8	9		☐
Launched on time	1	2	3	4	5	6	7	8	9		☐
Within budget	1	2	3	4	5	6	7	8	9		☐
Team satisfaction	1	2	3	4	5	6	7	8	9		☐
Other (Please specify): _____	1	2	3	4	5	6	7	8	9		

A new product development (NPD) project is defined for this survey as a project involving the development of a new product, a major change to an existing product, or an incremental change to an existing product.

3. Please indicate the approximate percentage of NPD projects undertaken during the past two years that, when they were started, had greater than a 50% chance of failing: _____ %

4. Please indicate the approximate percentage of NPD projects undertaken during the past two years that actually did fail: _____ %

5. Please indicate the approximate number of products developed by your organization during the past two years that fall into the following categories:

_____ New to the world
 _____ New to the country
 _____ New to the firm
 _____ Major revision to an existing product
 _____ Incremental change to an existing product

6. Thinking of the average size NPD project in your organization, please indicate the approximate number of NPD projects undertaken during the past two years that fall into the following categories in terms of the financial resources required:

_____ Very large project
 _____ Large project
 _____ Medium project
 _____ Small project
 _____ Very small project

7. Please indicate the general complexity of the NPD projects undertaken by your organization during the past two years:

In general, on NPD projects the ...	Is very low									Is very high	Unable to rate
	1	2	3	4	5	6	7	8	9		
Number of working person days	1	2	3	4	5	6	7	8	9		☐
Number of disciplines involved	1	2	3	4	5	6	7	8	9		☐
Number of people involved in developing the product within the company	1	2	3	4	5	6	7	8	9		☐
Number of design personnel involved	1	2	3	4	5	6	7	8	9		☐
Number of people involved external to the company	1	2	3	4	5	6	7	8	9		☐
Number of design changes in the late stages of the project	1	2	3	4	5	6	7	8	9		☐

8. Please check the functional disciplines typically involved in the NPD projects in your organization: (Please check all that apply)

☐ R&D ☐ Design ☐ Engineering ☐ Manufacturing ☐ Marketing ☐ Finance
☐ Sales ☐ Suppliers ☐ Customers ☐ Planning ☐ Purchasing ☐ Quality
☐ Others: (Please specify) _____

9. Please indicate the overall extent of interaction between the functional disciplines typically involved in the NPD projects in your organization:

In General ...	Very Low			Moderate					Very High			Unable to Rate
Frequent communication between these functional disciplines when developing products is	1	2	3	4	5	6	7	8	9			☐
Open communication between these functional disciplines when developing products is	1	2	3	4	5	6	7	8	9			☐
Coordination of product development activities between these functional disciplines is	1	2	3	4	5	6	7	8	9			☐
Overall, the extent by which product development is viewed as a priority by these functional disciplines is	1	2	3	4	5	6	7	8	9			☐
Clarity of product development goals for each of these functional disciplines is	1	2	3	4	5	6	7	8	9			☐
The amount these functional disciplines support one another when developing products is	1	2	3	4	5	6	7	8	9			☐
The ability of these functional disciplines to reach consensus regarding important product development issues is	1	2	3	4	5	6	7	8	9			☐
The extent these functional disciplines are involved in product development activities is	1	2	3	4	5	6	7	8	9			☐

A cross-functional new product development (NPD) team is defined for this survey as a product development team comprised of members representing various functional disciplines, such as design, manufacturing, engineering, R&D, marketing, customers, and suppliers.

10. Please check the box below that best describes how often your organization uses cross-functional teams on NPD projects: (Please check one box only)

- ☐ Cross-functional teams are used in _____% of NPD projects. Cross-functional NPD teams have been used for _____ years.
- ☐ Cross-functional NPD teams are currently being experimented with on a very limited basis.
- ☐ Cross-functional NPD teams have been adopted, but they have yet to actually be used.
- ☐ The use of cross-functional NPD teams is being considered for adoption.
- ☐ The use of cross-functional NPD teams was considered at one time, but the decision was made not to adopt.
- ☐ The use of cross-functional NPD teams has never been considered.

11. If your organization is using / considering using cross-functional NPD teams → Please proceed to Question 12

ELSE → Please proceed to Question 14.

12. Please indicate the appropriateness of the use / possible use of cross-functional NPD teams in your organization:

	Very Low				Moderate				Very High	Unable to rate
Employee support for cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Departmental management support for cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Senior management support for cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Ongoing financial cost of using / possibly using cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Complexity of using / possibly using cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Risks of using / possibly using cross-functional NPD teams are These risks are _____	1	2	3	4	5	6	7	8	9	☐
Benefits of using / possibly using cross-functional NPD teams are These benefits are _____	1	2	3	4	5	6	7	8	9	☐

13. If your organization is currently using cross-functional NPD teams, please indicate the extent that the following functional disciplines are represented on such teams:

	Never represented								Always represented	Unable to rate
R&D	1	2	3	4	5	6	7	8	9	☐
Design	1	2	3	4	5	6	7	8	9	☐
Engineering	1	2	3	4	5	6	7	8	9	☐
Manufacturing	1	2	3	4	5	6	7	8	9	☐
Marketing	1	2	3	4	5	6	7	8	9	☐
Finance	1	2	3	4	5	6	7	8	9	☐
Sales	1	2	3	4	5	6	7	8	9	☐
Planning	1	2	3	4	5	6	7	8	9	☐
Quality	1	2	3	4	5	6	7	8	9	☐
Purchasing	1	2	3	4	5	6	7	8	9	☐
Customers	1	2	3	4	5	6	7	8	9	☐
Suppliers	1	2	3	4	5	6	7	8	9	☐
Other (Please specify): _____	1	2	3	4	5	6	7	8	9	
Other (Please specify): _____	1	2	3	4	5	6	7	8	9	

A concurrent new product development (NPD) process is defined for this survey as the concurrent or overlapped execution of major product development activities, such as designing a product and its manufacturing process at the same time.

14. Please check the box below that best describes how often your organization uses concurrent processes on NPD projects: (please check one box only)

- ☐ Concurrent processes are used in _____ % of NPD projects. Concurrent NPD processes have been used for _____ years.
- ☐ Concurrent NPD processes are currently being experimented with on a very limited basis.
- ☐ Concurrent NPD processes have been adopted, but they have yet to actually be used.
- ☐ The use of concurrent NPD processes is being considered for adoption.
- ☐ The use of concurrent NPD processes was considered at one time, but the decision was made not to adopt.
- ☐ The use of concurrent NPD processes has never been considered.

15. If your organization is using / considering using concurrent NPD processes → Please proceed to Question 16

ELSE → Please proceed to Question 18.

16. Please indicate the appropriateness of the use / possible use of concurrent NPD processes in your organization:

	Very Low			Moderate				Very High		Unable to rate
Employee support for concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Departmental management support for concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Senior management support for concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Ongoing financial cost of using / possibly using concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Complexity of using / possibly using concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Risks of using / possibly using concurrent NPD processes are These risks are _____	1	2	3	4	5	6	7	8	9	☐
Benefits of using / possibly using concurrent NPD processes are These benefits are _____	1	2	3	4	5	6	7	8	9	☐

17. If your organization is using concurrent NPD processes, please list the major activities typically overlapped or performed concurrently:

18. Please make additional comments, if any, regarding the use of concurrent engineering in your organization.

Your comments will be combined with others and the content will be recorded anonymously.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There is no text or other markings on the paper.

Your contribution is appreciated. Thank you for completing this questionnaire.

Todd A. Boyle • Ph.D. Candidate

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Appendix 7

Survey Questions and Manifest Variables Mapping

Latent Variables	Manifest Variables	Question
CFT Support	Senior management support Department management support Employee support	12 A-C
CDP Support	Senior management support Department management support Employee support	16 A-C
CFT Diffusion Difficulty	Complexity Ongoing financial cost Risk Relative advantage	12D-G
CDP Diffusion Difficulty	Complexity Ongoing financial cost Risk Relative advantage	16D-G
Organization size	Captured from the on-line databases used to obtain the company contact information.	n/a
NPD Complexity	Number of NPD products Size of NPD projects Complexity of NPD projects Cost of NPD projects Risk of NPD projects Number of functional disciplines involved in NPD	7
NPD Strategy		5
Supportive Organizational Climate	Openness in decision making Collaboration Receptive to change Risk taking Bureaucratic	1
CFT Diffusion		10
CDP Diffusion		14
Communication Quality	Frequency of communication Open communication Coordination between the functional disciplines Extent by which NPD is viewed as a priority by the functional disciplines Extent that clear NPD goals exist for each of the functional Amount the functional disciplines support one another when developing new products Ability of the functional disciplines to reach consensus regarding important NPD issues Extent that functional disciplines are involved in NPD activities	9

<p>NPD Performance</p>	<p>Market share (%) Market position Return on investment Customer satisfaction Break-even time Profit margin Sales target Product performance vs. specification Quality standards Launched on time Within budget Team satisfaction</p>	<p>2</p>
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Appendix 8

Pilot Study Analysis

A8.1 Questionnaire Design Changes

As stated in Section 4.2, of the 65 questionnaires returned, six were unusable. The reasons for not using six of the questionnaires in the pilot study varied. For one questionnaire, the responding organization was no longer involved in NPD activities. For another, the responding organization's NPD activities took place outside of North America, violating the demographic constraint of the study. For another questionnaire, the individual to whom the questionnaire was addressed to was no longer with the organization, while another questionnaire was returned blank. For the final two questionnaires, questions which applied to the respondent's NPD activities were not completed. The unsuitability of the latter two questionnaires is believed to have been the result of a design flaw with the questionnaire used in the pilot study, specifically Questions 11 and 15. Question 11, presented in the Figure A8.1 is used to describe this flaw.

Figure A8.1

Questionnaire Design Flaw

For two questionnaires, both respondents indicated that they used cross-functional NPD teams. However, in both cases Question 12, which is directly below Question 11 was not answered. It is believed that these respondents may have seen the arrow pointing to the next page (i.e., as circled in Figure A8.1), and simply skipped to the next page, instead of reading the text after the arrow (i.e., please proceed to Question 12) and continuing below. This flaw is similar to question 15 which is focused on concurrent product development processes. This design flaw has since been fixed and thus these questions have been modified for the final version of the questionnaire. This change for cross-functional NPD teams is illustrated in Figure A8.2.

Figure A8.2

To capture the extent of IPD diffusion, the respondent is asked to answer the extent that cross-functional NPD teams and concurrent product development processes are used in the organization. Figure A8.3 illustrates how the extent of cross-functional NPD teams is captured on the questionnaire used for the pilot study.

Figure A8.3

Capturing Extent of Cross-Functional Teams

Please check the box below that best describes how often your organization uses cross-functional teams on NPD projects: (Please check one box only)

- ☐ Cross-functional teams are used in _____% of NPD projects. Cross-functional NPD teams have been used for _____ years.
- ☐ Cross-functional NPD teams are currently being experimented with on a very limited basis.
- ☐ Cross-functional NPD teams have been adopted, but they have yet to actually be used.
- ☐ The use of cross-functional NPD teams is being considered for adoption.
- ☐ The use of cross-functional NPD teams was considered at one time, but the decision was made not to adopt.
- ☐ The use of cross-functional NPD teams has never been considered.

Results of the pilot study indicate that two possible choices to answer this question were not selected by any of the respondents. These choices are “Cross-functional NPD teams have been adopted, but they have yet to actually be used” and “The use of cross-functional NPD teams was considered at one time, but the decision was made not to adopt”. Due to the lack of response to these questions, they have been dropped from the final questionnaire to increase white space. The revised question is illustrated in Figure A8.4.

Figure A8.4

Revised Extent of Cross-Functional Teams

Please check the box below that best describes how often your organization uses cross-functional teams on NPD projects: (Please check one box only)

- ☐ Cross-functional teams are used in _____% of NPD projects. Cross-functional NPD teams have been used for _____ years.
- ☐ Cross-functional NPD teams are currently being experimented with on a very limited basis.
- ☐ Cross-functional NPD teams are being considered for adoption.
- ☐ Cross-functional NPD teams are not being used.

In addition to the design change illustrated in Figure A8.4, after examining the pilot study data it is also apparent that placing two “Other (Please Specify):” items for Question 13 is not needed as no respondent completed both items and only one completed one item. As a result, one of these items has been removed to also increase white space on the questionnaire.

Analyzing the open ended sections of the questionnaire, many respondents gave comments regarding IPD in their organization. The fact that many respondents completed the open-end section has resulted in two new questions being added to the questionnaire, as illustrated in Figure A8.5.

Figure A8.5

New Open-Ended Questions

If cross-functional teams are not used on 100% of your organization's NPD projects:

Please state the major reasons why cross-functional teams are not used on all NPD projects.

If concurrent processes are not used on 100% of your organization's NPD projects:

Please state the major reasons why concurrent processes are not used on all NPD projects.

These questions are open ended and will be used to qualitatively support or deconstruct various model components and capture additional reasons, not addressed in this research, influencing the extent of diffusion of IPD in organizations.

The companies selected for the pilot study all contained at least 50 employees with no control for maximum size. Comments from one respondent indicated that product development managers representing very large organizations may have great difficulty answering the questionnaire. The main reason for such difficulty, and highlighted by the respondent, is that the respondents are asked to comment on their NPD activities in general, instead of focusing on one project that they are familiar with.

The respondent, for example, had a very difficult time determining the percentage of products the organization develops that fall into the categories of new-to-the-world, new-to-the-country, new-to-the-firm, major revision, and incremental change. The size of the organizations in the study will therefore be controlled. Only those organizations containing between 50-1000 employees will be addressed by this research study. As a result, and further discussed in Chapter Nine, generalizing the results of this study to very large organizations (i.e., 1000 + employees) must be approached with caution.

A8.2 Tests of Internal Consistency

The pilot study serves two major purposes. First, and the goal of Section 4.3, it allows for an examination of the design of the questionnaire, to identify any questions that could be removed or may need further clarification. Second, it allows for an examination of the measurement variables that comprise the various constructs of the research model.

Test of internal consistency are needed to examine the relationship between the measurement variables and their associated construct. The internal consistency test adopted for this research is Cronbach's alpha, which measures the internal consistency of the survey instrument where subjects respond to questions on a scale (e.g. 1-9 for this research). Cronbach's alpha can range between 0 and 1.

Cronbach's alpha depends on the strength of the inter-correlations of the items that make up the construct as well as the number of items that comprise the construct (Jackson, 2003). Jackson (2003) argues that since Cronbach's alpha is dependent upon both the number of items in the construct and the inter-item correlation between items in the construct, there is "no easy answer as to how high a value is required ... an alpha of .70 means one thing if there are 5 items in an index, but quite another if there are 14 items" (p. 399). Jackson (2003) highlights that as a "rule of thumb" the average inter-item correlations should be greater than 0.3 for a nine point Likert scale and develops a table to illustrate the minimum acceptable Cronbach's alpha levels for a given number of items. A subset of this table is illustrated in Table A8.1.

Table A8.1

**Minimum Cronbach's Alpha by
Mean Inter-Item Correlation and Number of Items**

# of Items	Alpha with Mean Inter-Item Correlation = 0.30	# of Items	Alpha with Mean Inter-Item Correlation = 0.30
2	0.462	9	0.794
3	0.562	10	0.811
4	0.632	11	0.825
5	0.682	12	0.837
6	0.720	13	0.848
7	0.750	14	0.857
8	0.774	15	0.865

Of the 59 questionnaires returned, two are from organizations with more than 1000 employees. As a result, two questionnaires fall outside the size constraint of this research study, and therefore have been excluded from further analysis. The constructs tested for internal consistency include *Innovative Organizational Climate*, *NPD Complexity*,

Practice Diffusion Difficulty, Member Support, *Communication Quality*, and *NPD Performance*.

An *Innovative Organizational Climate* is captured for this research study using five items, specifically openness in decision making (i.e., CULOPN), collaboration (i.e., CULCOL), receptive to change (i.e., CULREC), risk taking (i.e., CULRISK), and bureaucratic (i.e., CULBREV), which is reverse coded. Running SPSS, the output listing the internal consistency of the construct *Innovative Organizational Climate* is listed in Table A8.2.

Table A8.2

Internal Consistency of Innovative Organizational Climate

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
CULOPEN	23.7895	31.8477	.5955	.6942
CULCOL	23.6842	31.4342	.7128	.6654
CULREC	24.3684	27.3440	.6776	.6539
CULRISK	24.6491	29.2318	.4787	.7384
CULBREV	24.7719	35.4292	.2710	.8031

Reliability Coefficients

N of Cases = 57.0

N of Items = 5

Alpha = .7577

Examining Table A8.2, Cronbach's alpha at 0.7577 is greater than the minimal acceptable level (i.e., Table A8.1) for a five-item construct of 0.682. The construct *Innovative Organizational Climate* is therefore internally consistent. Although, removing *bureaucratic* from the construct would slightly improve Cronbach's alpha, it will be left in the study due to the support for this item in the literature.

NPD Complexity captures the general complexity of the organization's NPD activities. *NPD Complexity* is captured by the number of working person days (i.e., WORKPD), number of disciplines involved in NPD projects (i.e., NUMDISC), number of functions involved in developing the product in the organization (i.e., PWITHIN), number of design personnel involved in developing products in the organization (i.e., DESIGNP), number of people external to the organization involved in developing new products (i.e., PEXTERNAL). Examining Table A8.3, Cronbach's alpha for *NPD Complexity* at 0.7794 is greater than minimal acceptable level for a five-item construct of 0.682.

Table A8.3

Internal Consistency of NPD Complexity

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
WORKPD	17.4808	35.1957	.4724	.7637
NUMDISC	18.2115	31.4250	.6081	.7203
PWITHIN	18.8462	31.0739	.6023	.7218
DESIGNP	19.8462	30.0151	.6032	.7211
PEXTERNAL	21.0000	32.8235	.4869	.7614

Reliability Coefficients

N of Cases = 52.0

N of Items = 5

Alpha = .7794

Member support captures the support for IPD by members of the organization that are most impacted by its usage. As IPD is captured by cross-functional teams and concurrent product development processes, member support for IPD is captured by senior management support for cross-functional teams (i.e., SNRCFT) and concurrent product development processes (i.e., SNRCDP), department managerial support for cross-functional teams (i.e., DEPCFT) and concurrent product development processes (i.e., DEPCDP), and employee support for cross-functional teams (i.e., EMPCFT) and concurrent product development processes (i.e., EMPCDP). As cross-functional teams and concurrent development processes will be examined as separate constructs, two tests of internal consistency are needed, one for employee, department, and senior management support for cross-functional teams and one for employee, department, and senior management support for concurrent product development processes. Examining Table A8.4, it is apparent that the construct is internally consistent, as Cronbach's alphas at 0.8744 and 0.8303 are far greater than the minimal acceptable level for a three-item index of 0.562.

Table A8.4**Internal Consistency of Member Support**

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
EMPCFT	14.1600	11.8106	.6920	.8817
DEPTCFT	14.0400	10.2841	.8602	.7261
SNRCFT	13.5600	11.7208	.7297	.8480

Reliability Coefficients

N of Cases = 50.0

N of Items = 3

Alpha = .8744

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
EMPCDP	14.0238	12.7067	.6036	.8457
DEPCDP	14.0238	8.7555	.8655	.5699
SNRCDP	13.4762	10.8409	.6276	.8290

Reliability Coefficients

N of Cases = 42.0

N of Items = 3

Alpha = .8303

Practice diffusion difficulty is captured by the complexity, ongoing financial cost, risk, and relative advantage (i.e., reverse coded) of using a specific IPD practice. Table A8.5 lists the results of performing a reliability analysis on Practice Diffusion Difficulty using SPSS. As with the Member Support, Practice Diffusion Difficulty must be broken down into the diffusion difficulty for cross-functional teams and for concurrent product development processes.

Table A8.5**Internal Consistency of Practice Diffusion Difficulty**

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
COSTCFT	10.1628	14.4729	.3369	.5233
CPLXCFT	10.2791	13.0631	.5329	.3516
RISKCFT	11.2326	12.1827	.5189	.3514
BENCFTR	12.4186	20.7730	.0632	.6750

Reliability Coefficients

N of Cases = 43.0

N of Items = 4

Alpha = .5750

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
COSTCDP	10.8438	26.6522	.6632	.7818
CPLXCDP	10.3125	21.8347	.8265	.6981
RISKCDP	11.0938	20.5393	.7371	.7565
BENCDPR	12.6563	35.0716	.4936	.8568

Reliability Coefficients

N of Cases = 32.0

N of Items = 4

Alpha = .8292

Analyzing the results of the test, it is apparent that the IPD practice benefit variable is significantly lowering the internal consistency of Practice Diffusion Difficulty for both cross-functional NPD teams and concurrent product development processes. In addition, Cronbach's alpha for Cross-Functional NPD Team Diffusion Difficulty at 0.575 is below the minimal acceptable level for a four-item index of 0.632.

Given its impact on Cronbach's alpha and the fact that Practice Diffusion Difficulty is a new construct generated for this research (i.e., there is a lack of prior research on this specific construct), the IPD benefit item is dropped for this research study. Re-running reliability analysis with the IPD benefits item removed from both cross-functional teams and concurrent product development process provides a much more internally consistent constructs, resulting in Cronbach's alphas of 0.6711 and 0.8501 respectively; above the minimal acceptable level of 0.562.

Table A8.6

Practice Diffusion Difficulty – Benefits Item Removed

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
COSTCFT	7.8409	10.9741	.4302	.6461
CPLXCFT	7.9091	10.2241	.6016	.4276
RISKCFT	8.9318	10.7162	.4319	.6467

Reliability Coefficients

N of Cases = 44.0

N of Items = 3

Alpha = .6711

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
COSTCDP	8.6765	18.7709	.6626	.8478
CPLXCDP	8.0294	14.3930	.8511	.6599
RISKCDP	8.8824	14.5918	.6777	.8468

Reliability Coefficients

N of Cases = 34.0

N of Items = 3

Alpha = .8501

Communication Quality captures the extent that the IPD practices selected by the organization actually enable better integration and coordination of NPD activities. *Communication Quality* is captured by the frequency of communication between the functional disciplines involved in NPD (i.e., FREQCOM), extent of open communication between the functional disciplines involved in NPD (i.e., OPENCOM), the extent that the NPD goals are understood by the functional disciplines involved in NPD (i.e., CLARITY), the coordination between the functional disciplines involved in NPD (i.e., COORDIN), amount the functional disciplines support one another when developing new products (i.e., SUPPORT), the ability of the functional disciplines to reach consensus regarding important NPD issues (i.e., CONSENSUS), the extent by which NPD is viewed as a priority by the functional disciplines involved in NPD (i.e., PRIORITY), and the extent that functional disciplines are involved in NPD activities (i.e., FUNINVOL). Performing reliability analysis on *Communication Quality* (i.e., Table A8.7) produces a Cronbach's alpha of 0.9186, above the minimal acceptable level for an eight-item index of 0.774.

Table A8.7

Internal Consistency of Communication Quality

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
FRECOM	40.9245	103.5711	.6450	.9146
OPENCOM	40.6981	98.4071	.8327	.8999
COORDIN	41.2075	99.7830	.7819	.9039
PRIORITY	41.3019	99.5610	.7659	.9050
CLARITY	41.3396	102.3824	.6174	.9176
SUPPORT	41.0000	101.6154	.7249	.9084
CONSENSUS	40.8302	100.7591	.6480	.9153
FUNINVOL	41.1698	96.2975	.8439	.8984

Reliability Coefficients

N of Cases = 53.0

N of Items = 8

Alpha = .9186

The construct *NPD Performance* is comprised of 13 variables. These variables include market share (%)(i.e., MKTSHR), market position (i.e., MKTPOS), return on investment (i.e., ROI), customer satisfaction (i.e., CUSTSAT), break-even time (i.e., BETIME), profit margin (i.e., PROFITM), sales target (i.e., SALEST), product performance vs. specification (i.e., PERSPEC), quality standards (i.e., QUALSTD), launched on time (i.e., LAUNCH), within budget (i.e., BUDGET), and team satisfaction (i.e., TEAMSAT), and late design changes which is reverse coded (i.e., DESCHGR). Table A8.8 lists the results of performing a reliability analysis on *NPD Performance*.

Table A8.8

Internal Consistency of NPD Performance

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Alpha if Item Deleted
MKTSHR	73.0698	181.1617	.5587	.8816
MKTPOS	72.9302	181.3522	.6572	.8776
ROI	73.0233	173.9280	.6655	.8760
CUSTSAT	71.5349	195.4452	.3860	.8886
BETIME	73.0000	172.0476	.7101	.8736
PROFITM	73.0930	171.0388	.7274	.8726
SALEST	73.3023	172.4064	.7350	.8725
PERSPEC	71.6047	187.7685	.4244	.8878
QUALSTD	71.5349	185.5404	.5972	.8806
LAUNCH	73.4186	177.4873	.5020	.8859
BUDGET	73.2326	171.8494	.6552	.8766
TEAMSAT	72.2093	182.9313	.6522	.8782
DESCHGR	73.5349	186.5404	.3545	.8934

Reliability Coefficients

N of Cases = 43.0

N of Items = 13

Alpha = .8888

Examining the results of the reliability analysis, it is apparent that *NPD Performance* is internally consistent with a Cronbach's alpha of 0.8888, which is above the minimal acceptable level for a thirteen-item index of 0.848. Although removing design changes (i.e., DESCHGR) from the construct would slightly improve alpha, it is kept in the model due to the need to examine a wide variety of measures of *NPD Performance* and the support in the literature regarding IPD usage and reduction in the number of changes in the late stages of the NPD process.

Appendix 9
Revised Questionnaire

Survey Number: _____

Survey of Concurrent Engineering

Thank you for completing this questionnaire.

Your input is very much appreciated.

Results of individual questionnaires are confidential and will not be disclosed to any outside parties. Anonymity will be ensured by assigning numbers to individual questionnaires and combining the results of individual questionnaires when reporting the research findings.

1. Please indicate the extent that the following describes your organization:

	Not at all			Moderately			Extremely			Unable to rate
It incorporates values of openness in decision making	1	2	3	4	5	6	7	8	9	☐
It incorporates values of collaboration	1	2	3	4	5	6	7	8	9	☐
It is receptive to change	1	2	3	4	5	6	7	8	9	☐
It is risk taking	1	2	3	4	5	6	7	8	9	☐
It is bureaucratic	1	2	3	4	5	6	7	8	9	☐

2. Thinking of the products your organization has developed in the past two years, please indicate the extent that the following success criteria are generally met:

In General ...

In General ...	Is never met					Is always met					Unable to rate
Market share (%)	1	2	3	4	5	6	7	8	9	☐	
Market position	1	2	3	4	5	6	7	8	9	☐	
Return on investment	1	2	3	4	5	6	7	8	9	☐	
Customer satisfaction	1	2	3	4	5	6	7	8	9	☐	
Break-even time	1	2	3	4	5	6	7	8	9	☐	
Profit margin	1	2	3	4	5	6	7	8	9	☐	
Sales target	1	2	3	4	5	6	7	8	9	☐	
Product performance vs. specification	1	2	3	4	5	6	7	8	9	☐	
Quality standards	1	2	3	4	5	6	7	8	9	☐	
Launched on time	1	2	3	4	5	6	7	8	9	☐	
Within budget	1	2	3	4	5	6	7	8	9	☐	
Team satisfaction	1	2	3	4	5	6	7	8	9	☐	
Other (Please specify): _____	1	2	3	4	5	6	7	8	9		

A new product development (NPD) project is defined for this survey as a project involving the development of a new product, a major change to an existing product, or an incremental change to an existing product.

3. Please indicate the approximate percentage of NPD projects undertaken during the past two years that, when they were started, had greater than a 50% chance of failing: _____ %

4. Please indicate the approximate percentage of NPD projects undertaken during the past two years that actually did fail: _____ %

5. Please indicate the approximate number of products developed by your organization during the past two years that fall into the following categories:

_____ New to the world
 _____ New to the country
 _____ New to the firm
 _____ Major revision to an existing product
 _____ Incremental change to an existing product

6. Thinking of the average size NPD project in your organization, please indicate the approximate number of NPD projects undertaken during the past two years that fall into the following categories in terms of the financial resources required:

_____ Very large project
 _____ Large project
 _____ Medium project
 _____ Small project
 _____ Very small project

7. Please indicate the general complexity of the NPD projects undertaken by your organization during the past two years:

In general, on NPD projects the ...	Is very low									Is very high	Unable to rate
Number of working person days	1	2	3	4	5	6	7	8	9		☐
Number of disciplines involved	1	2	3	4	5	6	7	8	9		☐
Number of people involved in developing the product within the company	1	2	3	4	5	6	7	8	9		☐
Number of design personnel involved	1	2	3	4	5	6	7	8	9		☐
Number of people involved external to the company	1	2	3	4	5	6	7	8	9		☐
Number of design changes in the late stages of the project	1	2	3	4	5	6	7	8	9		☐

8. Please check the functional disciplines typically involved in the NPD projects in your organization:
 (Please check all that apply)

☐ R&D ☐ Design ☐ Engineering ☐ Manufacturing ☐ Marketing ☐ Finance
☐ Sales ☐ Suppliers ☐ Customers ☐ Planning ☐ Purchasing ☐ Quality
☐ Others: (Please specify) _____

9. Please indicate the overall extent of interaction between the functional disciplines typically involved in the NPD projects in your organization:

In General ...	Very Low			Moderate					Very High			Unable to Rate
Frequent communication between these functional disciplines when developing products is	1	2	3	4	5	6	7	8	9			☐
Open communication between these functional disciplines when developing products is	1	2	3	4	5	6	7	8	9			☐
Coordination of product development activities between these functional disciplines is	1	2	3	4	5	6	7	8	9			☐
Overall, the extent by which product development is viewed as a priority by these functional disciplines is	1	2	3	4	5	6	7	8	9			☐
Clarity of product development goals for each of these functional disciplines is	1	2	3	4	5	6	7	8	9			☐
The amount these functional disciplines support one another when developing products is	1	2	3	4	5	6	7	8	9			☐
The ability of these functional disciplines to reach consensus regarding important product development issues is	1	2	3	4	5	6	7	8	9			☐
The extent these functional disciplines are involved in product development activities is	1	2	3	4	5	6	7	8	9			☐

A cross-functional new product development (NPD) team is defined for this survey as a product development team comprised of members representing various functional disciplines, such as design, manufacturing, engineering, R&D, marketing, customers, and suppliers.

10. Please check the box below that best describes how often your organization uses cross-functional teams on NPD projects: (Please check one box only)

- ☐ Cross-functional teams are used in _____% of NPD projects. Cross-functional NPD teams have been used for _____ years.
- ☐ Cross-functional NPD teams are currently being experimented with on a very limited basis.
- ☐ Cross-functional NPD teams are being considered for adoption.
- ☐ Cross-functional NPD teams are not being used.

11. If cross-functional teams are not used on 100% of your organization's NPD projects:

Please state the major reasons why cross-functional teams are not used on all NPD projects.

12. Is your organization using cross-functional NPD teams?

YES: Please proceed to

Question 13

NO: Please proceed to

Question 15

13. Please indicate the appropriateness of the use of cross-functional NPD teams in your organization:

	Very Low			Moderate			Very High			Unable to rate
Employee support for cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Departmental management support for cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Senior management support for cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Ongoing financial cost of using cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Complexity of using cross-functional NPD teams is	1	2	3	4	5	6	7	8	9	☐
Risks of using cross-functional NPD teams are	1	2	3	4	5	6	7	8	9	☐
These risks are _____										

14. Please indicate the extent that the following functional disciplines are represented on your organization's cross-functional NPD teams:

	Never represented						Always represented			Unable to rate
R&D	1	2	3	4	5	6	7	8	9	☐
Design	1	2	3	4	5	6	7	8	9	☐
Engineering	1	2	3	4	5	6	7	8	9	☐
Manufacturing	1	2	3	4	5	6	7	8	9	☐
Marketing	1	2	3	4	5	6	7	8	9	☐
Finance	1	2	3	4	5	6	7	8	9	☐
Sales	1	2	3	4	5	6	7	8	9	☐
Planning	1	2	3	4	5	6	7	8	9	☐
Quality	1	2	3	4	5	6	7	8	9	☐
Purchasing	1	2	3	4	5	6	7	8	9	☐
Customers	1	2	3	4	5	6	7	8	9	☐
Suppliers	1	2	3	4	5	6	7	8	9	☐
Other (Please specify): _____	1	2	3	4	5	6	7	8	9	

A concurrent new product development (NPD) process is defined as the concurrent or overlapped execution of major product development activities, such as designing a product and its manufacturing process at the same time.

15. Please check the box below that best describes how often your organization uses concurrent processes on NPD projects: (please check one box only)

- ☐ Concurrent processes are used in _____% of NPD projects. Concurrent NPD processes have been used for _____ years.
- ☐ Concurrent NPD processes are currently being experimented with on a very limited basis.
- ☐ Concurrent NPD processes are being considered for adoption.
- ☐ Concurrent NPD processes are not being used.

16. If concurrent processes are not used on 100% of your organization's NPD projects:

Please state the major reasons why concurrent processes are not used on all NPD projects.

17. Is your organization using concurrent NPD processes?

YES: Please proceed to

Question 18

NO: Please proceed to

Question 20

18. Please indicate the appropriateness of the use of concurrent NPD processes in your organization:

	Very Low			Moderate			Very High			Unable to rate
Employee support for concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Departmental management support for concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Senior management support for concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Ongoing financial cost of using concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Complexity of using concurrent NPD processes is	1	2	3	4	5	6	7	8	9	☐
Risks of using concurrent NPD processes are	1	2	3	4	5	6	7	8	9	☐
These risks are _____										

19. Please list the major NPD activities typically overlapped or performed concurrently:

Your comments will be combined with others and the content will be recorded anonymously.

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Todd A. Boyle • Ph.D. Candidate

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Appendix 10

QSR Nud*ist Output for Cross-Functional NPD Team Risks

Q.S.R. NUD.IST Power version, revision 4.0.
Licensee: Technology Support Group.

PROJECT: npdproject1, User Todd Boyle, 11:58 am, May 9, 2003.

(T 8) //Text Searches/TextSearch199

*** Definition:

Search for '13', No restriction

+++++

+++ ON-LINE DOCUMENT: QUALDATA2

+++ Retrieval for this document: 73 units out of 916, = 8.0%

++ Text units 14-14:

Q13) Time, efficiency while sharing job duties

++ Text units 32-32:

Q13) Very low eg. Failure to reach a consensus on an issue

++ Text units 36-36:

Q13) Too many meetings over engineering

++ Text units 48-48:

Q13) Lower efficiency of participants in daily tasks not related to NPD.

++ Text units 67-67:

Q13) Time, resources

++ Text units 91-91:

Q13) Different agendas, difficulties in achieving consensus

++ Text units 102-102:

Q13) Timeline tasks either not being completed or not being fully, with no prior advanced warning.

++ Text units 124-124:

Q13) Interruptions to non-project tasks.

++ Text units 135-135:

Q13) Accountability & pursuing agendas rather than production goals

++ Text units 141-141:

Q13) Related to competition between disciplines

++ Text units 165-165:

Q13) Time spent on getting team members up to speed

++ Text units 184-184:

Q13) Errors in design or manufacturing

++ Text units 191-191:

Q13) Not making decisions, just argue

++ Text units 245-245:

Q13) Concerns of some that they're having shoulders looked over.

++ Text units 256-256:

Q13) Goals drift, slower project unless project engineer pushes.

++ Text units 265-265:

Q13) Dilution of resources that could be deployed on independent projects.

++ Text units 270-270:

Q13) Delays

++ Text units 318-318:

Q13) Interruption of other functional duties in a lean business

++ Text units 337-337:

Q13) Schedule slip
 ++ Text units 343-343:
 Q13) One group not keeping up with others changes
 ++ Text units 365-365:
 Q13) New product development leaked to competitors.
 ++ Text units 382-382:
 Q13) Personally conflicts lack direction from sales.
 ++ Text units 394-394:
 Q13) Poor NPD team leadership. Poor leadership reflects poorly on the project which induces negative feelings about the task ahead and can result in minimal efforts at teamwork. The political support capital becomes diminished
 ++ Text units 426-426:
 Q13) Increased development time resource issues
 ++ Text units 445-445:
 Q13) Lack of other teams or company wide support
 ++ Text units 451-451:
 Q13) Priority or focus distracted for the wrong reasons
 ++ Text units 461-461:
 Q13) The possibility of team members not dedicating enough effort to the team
 ++ Text units 480-480:
 Q13) Longer development times
 ++ Text units 490-490:
 Q13) Reaching consensus quickly avoiding drift in focus, sticking to the plan.
 ++ Text units 494-494:
 Q13) Cost of manpower
 ++ Text units 516-516:
 Q13) Lack of sufficient communication
 ++ Text units 535-535:
 Q13) Schedule
 ++ Text units 547-547:
 Q13) Negative remarks
 ++ Text units 563-563:
 Q13) More benefit than risk
 ++ Text units 579-579:
 Q13) Timing of priorities are different for each function
 ++ Text units 585-585:
 Q13) Cost and (?)
 ++ Text units 619-619:
 Q13) Overload in one dept.
 ++ Text units 646-646:
 US-1384
 ++ Text units 648-648:
 Q13) Time taken away from other duties of team members, goals, objectives, etc.
 ++ Text units 655-655:
 Q13) Timely access to the team members who matrix across several projects concurrently
 ++ Text units 663-663:
 Q13) Deleterious effect on operations since team members also have operational responsibilities
 ++ Text units 674-674:
 Q13) Too many cooks unclear ownership of some tasks or assets.
 ++ Text units 681-681:
 Q13) Lack of communication and commitment
 ++ Text units 686-686:

Q13) Reaction time slower
 ++ Text units 693-693:
 Q13) Added expense of multiple people and possible slowing of the development cycle VS fewer people
 Q13) Control/focus
 ++ Text units 715-715:
 Q13) Unioned employees hear numbers they shouldn't hear.
 ++ Text units 747-747:
 Q13) Employee changeover
 ++ Text units 758-758:
 Q13) Decision by committee, inability to reach consensus and make decision
 ++ Text units 788-788:
 Q13) Specification/performance
 ++ Text units 794-794:
 Q13) Politics and bureaucratic
 ++ Text units 802-802:
 Q13) Competing resource allocation with functional groups
 ++ Text units 816-816:
 Q13) Higher cost
 ++ Text units 823-823:
 Q13) Loss of project control and accountability
 ++ Text units 846-846:
 Q13) Individual team members having to multi-task for other members
 ++ Text units 863-863:
 Q13) Personnel and time resources
 ++ Text units 867-867:
 Q13) Resource constraints
 ++ Text units 883-883:
 Q13) Time wasted
 ++ Text units 904-904:
 Q13) Creating a wasted production effort where the product does not pan out.

++++
 +++ Total number of text units retrieved = 73
 +++ Retrievals in 1 out of 1 documents, = 100%.
 +++ The documents with retrievals have a total of 916 text units, so text units retrieved in these documents
 +++ = 8.0%.
 +++ All documents have a total of 916 text units, so text units found in these documents = 8.0%.
 +++++

Appendix 11

QSR Nud*ist Output for NPD Activities Overlapped or Performed Concurrently

Q.S.R. NUD.IST Power version, revision 4.0.
Licensee: Technology Support Group.

PROJECT: npdproject1, User Todd Boyle, 12:55 pm, May 9, 2003.

(T 10) //Text Searches/TextSearch201

*** Definition:

Search for '19)', No restriction

+++++

+++ ON-LINE DOCUMENT: QUALDATA2

+++ Retrieval for this document: 123 units out of 916, = 13%

++ Text units 3-3:

Q19) Engineering, Manufacturing, Purchasing and Sales

++ Text units 16-16:

Q19) Component routing, SCM, BOM, Occasionally methods, Costing

++ Text units 22-22:

Q19) Engineering and MFG, Engineering and Material Sourcing

++ Text units 33-33:

Q19) Design, Engineering & MFG, Working together to come up with a practical solution to marketing needs.

++ Text units 38-38:

Q19) Design/Engineering/Planning/MFG

++ Text units 41-41:

Q19) Product design & development, MFG process & development

++ Text units 51-51:

Q19) R&D and market research/engineering & MFG, Engineering & Product Support (After Sales)

++ Text units 62-62:

Q19) New product to the firm and completely new to the world. All activities require a percentage of concurrency.

++ Text units 73-73:

Q19) Sheet material design --> shop controls and wiring follow

++ Text units 77-77:

Q19) R&D, design & product engineering, quality assurance, manufacturing process validation (tooling and equipment), supplier involvement.

++ Text units 84-84:

Q19) Design, Engineering, Purchasing, MFG, Sales, Materials

++ Text units 94-94:

Q19) Design, MFG, process development

++ Text units 98-98:

Q19) Requirement Definition and preliminary design, (final) Design and Qualification testing, Qual. Test and MFG/Purchasing

++ Text units 109-109:

Q19) Eng, design, tooling, MFG ENG, IS-Order systems integration, purchasing and materials procurement.

++ Text units 126-126:

Q19) Spec Writing, Release Plans, Test Plans

++ Text units 131-131:

Q19) Manufacturing & marketing concurrent with design/engineering
 ++ Text units 136-136:

Q19) Sales-design, R&D, design-engineering-finance,
 planning-design-engineering-manufacturing, Finance-suppliers-purchase
 ++ Text units 143-143:

Q19) Engineering/purchasing, Engineering/Manufacturing
 ++ Text units 153-153:

Q19) ENG/Design/MFG
 ++ Text units 156-156:

Q19) Product design, Tooling Design/Build, Routing Layout, Model Numbering
 ++ Text units 161-161:

Q19) Product Design & Manufacturing process/Quality Planning
 ++ Text units 167-167:

Q19) Design, MFG, and purchasing
 ++ Text units 172-172:

Q19) Design of product, development of product, purchasing of parts,
 testing of product, sales of product, manufacturing of product.
 ++ Text units 175-175:

Q19) Engineering design to manufacturing capabilities, sales requirement
 to production capabilities. Customer expectations to quality produced.
 ++ Text units 186-186:

Q19) Design-engineering-manufacturing with customer and vendor support.
 ++ Text units 193-193:

Q19) Seal type & design for application, hydraulic cylinder design,
 application unique.
 ++ Text units 199-199:

Q19) Design, prototyping, engineering, too-up, fixturing.
 ++ Text units 214-214:

Q19) Design, Manufacturing processing, tooling design, marketing planning
 ++ Text units 218-218:

Q19) Product design/Marketing & customer review & field
 testing/Manufacturing process development/packaging, graphics,
 manuals/materials procurement.
 ++ Text units 223-223:

Q19) ENG, Design, MFG, purchasing, marketing.
 ++ Text units 226-226:

Q19) Mold design to ease trimming operations, trim to ease secondary
 clean-up, etc.
 ++ Text units 233-233:

Q19) Design/product specs., Manufacturing/design, Supplier
 involvement/design
 ++ Text units 239-239:

Q19) NPD is usually used with business functions. Concurrent is used more
 got ENG/MFG.
 ++ Text units 246-246:

Q19) R&D, Design (5 people, one per project), MFG ENG Quality (one
 person), Production Planning, Schedule MFG (one person), Sales marketing
 (co. president, one person).
 ++ Text units 252-252:

Q19) Research, development, procurement, manufacturing, marketing.
 ++ Text units 258-258:

Q19) Purchases of tooling/inventory while larger sizes of product family
 are being developed. Catalog creation, pricing/costing
 ++ Text units 267-267:

Q19) Design ENG, MFG, Sourcing, MKT.
 ++ Text units 285-285:

Q19) Suppliers recommendations, trial production runs, customer samples, collection of SPC data.
++ Text units 296-296:
Q19) Engineering and R&D, Engineering and Manufacturing, Sales and R&D/ENG
++ Text units 305-305:
Q19) Design and MFG
++ Text units 310-310:
Q19) Ordering of long lead time parts, ATE system development and writing of factory work
++ Text units 327-327:
Q19) R&D, Design, ENG, MFG
++ Text units 334-334:
Q19) Major revisions to an existing project
++ Text units 340-340:
Q19) Design and production tooling
++ Text units 344-344:
Q19) PCB and chassis design (electrical/mechanical)
++ Text units 367-367:
Q19) Mechanical, electrical, software, purchasing
++ Text units 372-372:
Q19) Design, Validation testing, Process development, Process verification
++ Text units 377-377:
Q19) Marketing, Design & MFG
++ Text units 383-383:
Q19) Multiple new technologies affecting one type of product. Changes early in product MFG impacts all other downstream systems and these impacts are to be eliminated or minimized.
++ Text units 395-395:
Q19) For our organization --> Engineering & Manufacturing are the only 2 depts. extensively overlapped.
++ Text units 399-399:
Q19) New machine designs build on existing technology
++ Text units 404-404:
Q19) Involvement /w design & MFG process capability tied to customer so that DWG's and expectations are aligned /w all areas.
++ Text units 409-409:
Q19) Product definition, product development, quality assurance.
++ Text units 413-413:
Q19) MFG, Design, Quality, Supply Mgmt, etc. all sit on the same team. So this is happening all at the same time.
++ Text units 423-423:
Q19) Design, prototype and production pricing
++ Text units 431-431:
Q19) Tooling developed while design evolves
++ Text units 434-434:
Q19) R&D, Marketing and Engineering
++ Text units 447-447:
Q19) Tooling on programming design /w around amounts.
++ Text units 455-455:
Q19) Requirement definition, and prototype development, production process and design validation and verification
++ Text units 463-463:
Q19) Supplier development and tooling, MFG process development
++ Text units 469-469:
Q19) Design, MFG ENGR, Quality planning, tooling design, mold flow, DFA, FEA, FMEA, DFMEA.

++ Text units 475-475:
 Q19) ENGR, Test, MFG
 ++ Text units 481-481:
 Q19) Design, NC cutting tool paths of parts performed concurrently
 ++ Text units 485-485:
 Q19) Mechanical, electrical, software, ENG
 ++ Text units 491-491:
 Q19) All portions of projects are executed using concurrent processing techniques with MS Project linked across organizations. Priorities set based on bottleneck analysis with resource applied accordingly.
 ++ Text units 505-505:
 Q19) Product design/development, Vendor/Supplier development, MFG line/process development
 ++ Text units 510-510:
 Q19) DFMEA, PFMEA, layout, process viability of assembly
 ++ Text units 518-518:
 Q19) Design, manufacturing flow
 ++ Text units 523-523:
 Q19) Design/project mgmt/project engineering/MFG
 ++ Text units 530-530:
 Q19) Customer communications through sales and ENG.
 ++ Text units 537-537:
 Q19) Engineering and purchasing, purchasing and quality
 ++ Text units 548-548:
 Q19) Engineering/MFG
 ++ Text units 554-554:
 Q19) Marketing, concepting
 ++ Text units 558-558:
 Q19) Design, Test, Production equipment ready, purchasing
 ++ Text units 565-565:
 Q19) Design and material acquisition (planning, procurement, mfg), design and planning, construction and detailing (typically alpha build)
 ++ Text units 569-569:
 Q19) Product design and mfg process of new products and water base
 ++ Text units 581-581:
 Q19) Design on preliminary state, and MFG. ENG develop process and predicting costs.
 ++ Text units 588-588:
 Q19) MFG process, design of product, marketing and sale launch materials.
 ++ Text units 593-593:
 Q19) All processes that can be performed concurrently and that make sense are.
 ++ Text units 599-599:
 Q19) Design and purchasing, design and MFG, market potential and design
 ++ Text units 603-603:
 Q19) Software/hardware design, electronic/mechanical design, purchasing/R&D
 ++ Text units 608-608:
 Q19) Marketing study and product specs, product prototyping and MFG process development
 ++ Text units 613-613:
 Q19) Design and development overlap with MFG
 ++ Text units 620-620:
 Q19) Design review, design update
 ++ Text units 628-628:
 Q19) Engineering documentation details, purchasing, planning

++ Text units 650-650:
Q19) Design for MFG, Design assembly so you cant put it together backwards etc. Design an assembly friendly part

++ Text units 658-658:
Q19) Design, MFG, Quality

++ Text units 672-672:
Q19) Software dev H/W prototyping, test process during design and prototyping

++ Text units 677-677:
Q19) Functional design of parts/Design of assembly tooling/ Design of test equipment

++ Text units 682-682:
Q19) Product specs; product design; product promotion; sales roll-out

++ Text units 695-695:
Q19) Finalization of design is performed while process detail and test methods are developed. Initial MFG plan is also developed and some materials ordered.

++ Text units 701-701:
Q19) Design, testing, assembly layout, quality control procedures, product literature, promotion, production planning (inventory buildup).

++ Text units 707-707:
Q19) Design, MFG engineering, purchasing, MFG

++ Text units 722-722:
Q19) Tooling design, marketing planning

++ Text units 725-725:
Q19) ENG design MFG, MFG controls programming

++ Text units 728-728:
Q19) Design, MFG process development, quality planning, FMEA's, logistics, etc.

++ Text units 732-732:
Q19) Tool making, circuit design, functional testing of sub assemblies

++ Text units 748-748:
Q19) Material development and the tooling required to process the materials. (We press powders into final shape via mechanical compactor)

++ Text units 753-753:
Q19) We have for 2 years now been on a project to reduce cost in our products with the support of MFG, tooling and procedures are developed along side the design phase of the new designed products.

++ Text units 761-761:
Q19) Design/acquisition of tools/fixtures, MFG process development, supplier selections, testing, publication of test data, marketing literature

++ Text units 766-766:
Q19) Finance/Design; ENG/R&D/MFG/MKT; Planning/MFG; Sales/MKT

++ Text units 777-777:
Q19) Product ENG and process ENG

++ Text units 785-785:
Q19) Lean MFG

++ Text units 790-790:
Q19) Electronic subassembly design/MFG, cable design, MFG mechanical subassembly

++ Text units 797-797:
Q19) 1) New products 2) Current product improvement 3) Small changes for current products.

++ Text units 806-806:
Q19) Design, prototype MFG, management of customer input

++ Text units 809-809:
 Q19) Design and MFG processes, design and costing
 ++ Text units 812-812:
 Q19) Product testing, production planning, capacity plans
 ++ Text units 818-818:
 Q19) PCB prototyping and final electronic circuit verification
 ++ Text units 825-825:
 Q19) Design and MFG and design and marketing
 ++ Text units 831-831:
 Q19) Design and process development along with quality systems planning
 ++ Text units 834-834:
 Q19) Concept --> MFG of composite structures
 ++ Text units 838-838:
 Q19) Material development/MFG/purchasing
 ++ Text units 841-841:
 Q19) Design of product and process
 ++ Text units 849-849:
 Q19) Design, financial control, MFG ENG, product ENG
 ++ Text units 857-857:
 Q19) Eng design, Mfg planning, supplier selection, marketing, aftermarket development, costing or financial modeling.
 ++ Text units 868-868:
 Q19) Product development, MFG ENG, Quality
 ++ Text units 873-873:
 Q19) R&D, Design criteria, sales information, MFG process
 ++ Text units 877-877:
 Q19) We use cross-functional design teams utilizing a milestone concept. Milestones are: design concept, conceptual design, product design to ENG samples, transfer to ENG pilot, ENG pilot, production pilot/& man production, feedback/ (?) and corrective action. Most of the milestones can be worked in concurrently.
 ++ Text units 889-889:
 Q19) Too extensive to list
 ++ Text units 895-895:
 Q19) Manufacturing, testing, evaluation
 ++ Text units 900-900:
 Q19) Design, tooling, fabrication.
 ++ Text units 906-906:
 Q19) R&D, Pilot Production, Marketing Feasibility.
 ++++++
 +++ Total number of text units retrieved = 123
 +++ Retrievals in 1 out of 1 documents, = 100%.
 +++ The documents with retrievals have a total of 916 text units, so text units retrieved in these documents
 +++ = 13%.
 +++ All documents have a total of 916 text units, so text units found in these documents = 13%.
 ++++++

Appendix 12

QSR Nud*ist Output for Concurrent Product Development Process Risks

Q.S.R. NUD.IST Power version, revision 4.0.

Licensee: Technology Support Group.

PROJECT: npdproject1, User Todd Boyle, 12:39 pm, May 9, 2003.

(T 9) //Text Searches/TextSearch200

*** Definition:

Search for '18)', No restriction

+++++

+++ ON-LINE DOCUMENT: QUALDATA2

+++ Retrieval for this document: 29 units out of 916, = 3.2%

++ Text units 37-37:

Q18) Over engineering

++ Text units 57-57:

Q18) Late delivery of product

++ Text units 125-125:

Q18) Interruptions to non-project tasks.

++ Text units 142-142:

Q18) Cost(s) of redesigning, reengineering, etc.

++ Text units 185-185:

Q18) Errors in design or manufacturing

++ Text units 198-198:

Q18) That engineering changes will scrap manufacturing equipment and increase costs.

++ Text units 257-257:

Q18) Purchases made too early, other depts.. not familiar with the fuzzy front end design work that engineers perform.

++ Text units 275-275:

Q18) Lot of rework

++ Text units 320-320:

Q18) Interruption of other functional duties in a lean business

++ Text units 339-339:

Q18) Schedule slip

++ Text units 440-440:

Q18) Resource issues training communication

++ Text units 504-504:

Q18) Design changes affecting completed processes requiring process changes

++ Text units 517-517:

Q18) Communication breakdowns

++ Text units 529-529:

Q18) Product use liabilities development of unfamiliar customer applications

++ Text units 580-580:

Q18) MFG executing a non-applicable or successful process

++ Text units 587-587:

Q18) Import from design changes

++ Text units 612-612:

Q18) (?) is oned out all the kinks in the project

++ Text units 676-676:
 Q18) Spending on MFG equipment that's unused because product doesn't go.
 ++ Text units 687-687:
 Q18) Over budget
 ++ Text units 694-694:
 Q18) May develop a process that gets changed before project is completed
 ++ Text units 698-698:
 Q18) Not a fine finish product
 ++ Text units 706-706:
 Q18) Poor communication
 ++ Text units 731-731:
 Q18) False starts
 ++ Text units 760-760:
 Q18) Changes impacting on tooling/marketing literature
 ++ Text units 789-789:
 Q18) Delays product launch
 ++ Text units 796-796:
 Q18) Politics and bureaucratic
 ++ Text units 805-805:
 Q18) Communication is a must
 ++ Text units 848-848:
 Q18) There are no risks
 ++ Text units 856-856:
 Q18) Having to rework or redo completed when the design changes.

++++++
 +++ Total number of text units retrieved = 29
 +++ Retrievals in 1 out of 1 documents, = 100%.
 +++ The documents with retrievals have a total of 916 text units, so text units retrieved in these documents
 +++ = 3.2%.
 +++ All documents have a total of 916 text units, so text units found in these documents = 3.2%.
 ++++++

Appendix 13

ANOVA for Country, NAICS Codes, and Organization Size

COUNTRY	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
	PRUSECF2	1.769	1	1.769	.002	.965
	PRUSECD2	198.067	1	198.067	.162	.688
	CLIMATEC	.001	1	.001	.001	.976
	NPDPERC	.041	1	.041	.043	.836
	QUALITYC	5.800E-06	1	5.800E-06	.000	.998
	NPDSTRAC	2.332	1	2.332	3.807	.053
	CFTSUPC	.009	1	.009	.005	.942
	CFTCPLXC	.428	1	.428	.232	.630
	CDPSUPC	1.397	1	1.397	.774	.380
	CDPCPLXC	.676	1	.676	.251	.617
	NPDCPLXC	1.635	1	1.635	.813	.369
	COSTCFT	.259	1	.259	.070	.792
	CPLXCFT	.420	1	.420	.116	.734
	RISKCFT	3.326	1	3.326	1.167	.282
	COSTCDP	.078	1	.078	.018	.894
	CPLXCDP	.001	1	.001	.000	.987
	RISKCDP	7.362	1	7.362	1.396	.239
	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
NAICS	PRUSECF2	1885.235	3	628.412	.701	.553
	PRUSECD2	3070.583	3	1023.528	.839	.474
	CLIMATEC	5.979	3	1.993	1.420	.239
	NPDPERC	1.379	3	.460	.476	.699
	QUALITYC	3.584	3	1.195	.937	.424
	NPDSTRAC	1.046	3	.349	.569	.636
	CFTSUPC	5.498	3	1.833	1.048	.374
	CFTCPLXC	6.858	3	2.286	1.242	.297
	CDPSUPC	7.515	3	2.505	1.388	.249
	CDPCPLXC	10.271	3	3.424	1.274	.286
	NPDCPLXC	8.863	3	2.954	1.470	.225
	COSTCFT	14.279	3	4.760	1.286	.281
	CPLXCFT	13.537	3	4.512	1.244	.296
	RISKCFT	5.197	3	1.732	.608	.611
	COSTCDP	16.061	3	5.354	1.227	.302
	CPLXCDP	27.500	3	9.167	2.300	.080
	RISKCDP	5.064	3	1.688	.320	.811

Organization Size	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
	PRUSECF2	670.868	2	335.434	.379	.685
	PRUSECD2	673.115	2	336.558	.274	.760
	CLIMATEC	.072	2	.036	.025	.975
	NPDPERC	4.280	2	2.140	2.270	.107
	QUALITYC	2.410	2	1.205	.964	.384
	NPDSTRAC	.702	2	.351	.574	.564
	CFTSUPC	3.382	2	1.691	.983	.377
	CFTCPLXC	1.146	2	.573	.308	.735
	CDPSUPC	6.065	2	3.032	1.701	.186
	CDPCPLXC	.002	2	.001	.000	1.000
	NPDCPLXC	8.323	2	4.162	2.087	.128
	COSTCFT	3.345	2	1.672	.453	.636
	CPLXCFT	3.213	2	1.607	.444	.642
	RISKCFT	9.705	2	4.852	1.701	.186
	COSTCDP	.531	2	.265	.061	.941
	CPLXCDP	6.381	2	3.190	.779	.460
	RISKCDP	11.243	2	5.622	1.082	.342