CONCURRENT ENGINEERING PRACTICES THAT REDUCE NEW PRODUCT DEVELOPMENT CYCLE TIME FOR INCREMENTAL AND RADICAL INNOVATION

By

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ABSTRACT

This research examines the concurrent engineering practices employed in Canadian Electronic Parts and Components organizations for reducing new product development cycle time of new (radical) and significantly improved (incremental) products.

The analysis and findings presented in this research describe the CE practices that are frequently used in NPD projects according to NPD managers of Canadian Electronic Parts and Components organizations, the extent to which these practices are effective in reducing NPD cycle time, and the gap, if any, between the actual usage of CE practices and the perceived usefulness of the CE practices in reducing NPD cycle time.

The model developed for this research explains how specific practices reduce the three measures of NPD cycle time; Time-to-Market, Concept-to-Customer, and Development Time, when the product under development is either completely new to the firm or a significant improvement of a pre-existing technology platform.

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Chapter 1 – Introduction

Depending on the industry they compete in, firms are required to engage in the continuous development of new products in order to remain competitive. Developing new or significantly improved products, however, is not enough for the modern knowledge-based competitive environment. New Product Development (NPD) must be complemented with the rapid introduction of new or significantly improved products in order to prevent obsolescence. Time-based strategies are an important part of competitive advantages. One method of achieving such an advantage is through Concurrent Engineering (CE)[1].

This research focuses on CE and the adoption of its practices in order to reduce NPD cycle time. This research examines the extent of use of CE practices in Electronic Parts and Components firms. The research identifies the critical CE practices for reducing NPD cycle time[2], measured in terms of Time-to-Market (including Market Finding, New Product Strategy, Detailed Design and Prototype Development, Pre-Production and Production), Concept-to-Customer Time (from New Product Strategy until Production), and Development Time (from Detailed Design and Prototype Development until Production). Finally, this research looks at the existing gap, if any, between the actual usage of the CE practices and the perceived usefulness of the CE tools as seen by the NPD managers for reducing NPD cycle time.

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[1] CE is defined as "the earliest possible integration of the overall company's knowledge, resources, and experience in design, development, marketing, manufacturing, and sales into creating successful new products, with high quality and low cost, while meeting customer expectations. The most important result of applying CE is the shortening of the product concept, design and development process from a serial to a parallel one" (Shina, 1991). It is typically thought of as the "design of product and process in parallel" using human, organizational, and technology practices to succeed (Duffy and Salvendy, 1998 and 1999)
[2] The literature usually takes NPD cycle time from the point at which a concept is generated to the point at which it reaches the customer (Griffin, 1993). In this research NPD cycle time ends at production.

In order to answer the questions mentioned above a model has been developed. This model proposes a set of CE practices that influence NPD cycle time, which for the purposes of this research is measured in terms of three time variables just mentioned. Each time variable begins with a different stage of the NPD process but all end at the production stage. Time-to-Market includes Market Finding, New Product Strategy, Detailed Design and Prototype Development, Pre-production, and Production; Concept-to-Customer begins with the New Product Strategy stage; and Development Time begins with Detailed Design and Prototype Development. The relationship between the CE Practices and the three measures of time is moderated by the type of innovation being developed. The two types of innovation considered include incremental and radical innovation.

The major sections of this thesis are divided into chapters beginning with a review of the literature in Chapter 2. Chapter 3 explains the research objectives, the investigative questions, and a research model along with propositions to be tested for the relationship between the three measures of NPD cycle time and CE practices. Chapter 4 and 5 are the research methodology and data collection sections respectively. Chapter 6 discusses the data analysis and findings. Chapter 7 is the discussion and interpretations of the data analysis. Finally Chapter 8 concludes the study and provides the limitations, benefits and future research areas relating to this research.

(For a list of all acronyms used in this research see Appendix I.)

Chapter 2 – Literature Review

2.1 – Overview of New Product Development Issues

New Product Development includes a set of activities that moves a new product project from the point of idea generation to market launch and post implementation review. Many firms employ NPD as a means of pursuing future profitable growth. Variants of NPD include identifying a market opportunity and trying to match the needs of that market with the appropriate technology (i.e. market demand initiates the NPD process), seeking a market that might be interested in a newly developed technology (i.e. pushing the new technology onto a market), building a new product from pre-existing technology (e.g. platform product), or making slight variations to a product in order to customize it for individual market segments (Ribbens, 2000; Ulrich and Eppinger, 2000).

The success of NPD may be assessed by performance measures such as customer acceptance, customer satisfaction level, met revenue goals, revenue growth, break-even time, attainment of margin goals, attainment of profitability goals, internal rate of return, return on investment, cost of developing the product, on-time launching, technical performance of product, met quality guidelines, speed-to-market, and percent of sales provided by products less than 5 years old (Griffin and Page, 1993; Kleinschimdt and Cooper, 1995). In order to achieve success in such areas, NPD relies on five main critical factors: 1) senior management commitment; 2) supportive organizational structure and processes; 3) attractive new product concepts that are possible to develop; 4) appropriately staffed and resourced venture teams; and 5) reduction of uncertainties using project management. Together these allow for significant reduction in delays, time and money (Lester, 1998).

This research addresses the success of NPD by measuring the speed-to-market for products of firms within the Electronics Parts and Components Industry or similar type industries[3]. These fast-cycle industries often face short product life cycles and see speed as a key source of competitive advantage (Datar *et al.*, 1997). Speed essentially translates in the reduction of NPD cycle time and will be referred to as such throughout the remainder of this manuscript.

The interesting aspects of NPD and its cycle time arise from the measurement of these two elements. Initially, their meanings appear obvious yet with further examination it is evident they are more sophisticated than meets the eye. A new product, for instance, can refer to a product that functions, performs and appears differently or it may just be a product that is built upon pre-existing technology, but to the customer looks and performs different than before[4]. This research will be looking at both types, which the literature refers to as radical and incremental products. These two types of products are discussed in detail towards the end of this chapter, along with the differences in the NPD process that accompany them.

Finally, NPD is also discussed in terms of Integrated Product Development (IPD) and Concurrent Engineering (CE)[5], an interesting manifestation of IPD (Gerwin and Barrowman, 2001). CE and its practices are given considerable attention in this research especially as they relate to reduction in NPD cycle time.

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[3] Industries such as Aircraft and Parts, Telecommunication Equipment, Electronic or Electrical Industrial Equipment, were considered in addition to the Electronic Parts and Components firms.
[4] Ulrich and Eppinger (2000) refer to this type of product as a platform product.
[5] Concurrent Engineering (CE) is an integrated multi-disciplinary approach to product development whereby representatives from different departments collaborate together in order to communicate partial information with one another from the point of generating the product idea to putting the product on the market while meeting commonly shared product performance goals.

Table 2.0 depicts the different sections of this chapter through which the literature on NPD and NPD cycle time is reviewed.

Table 2.0 – Overview of Literature Review Sections

SECTION	CONTENT
2.1	Introduction to NPD issues.
2.2	Describes the New Product Development (NPD) process.
2.3	Defines Cycle Time and introduce Concurrent Engineering (CE) as a technique for reducing the time needed for the NPD process.
2.4	Links CE to NPD by explaining Integrated Product Development. Defines CE and contrasts it to the traditional NPD process.
2.5	Discusses each one of the practices of CE (people, process, tool, techniques and methods).
2.6	Considers how CE practices reduce NPD cycle time.
2.7	Defines and contrasts the major moderators of the study – radical and incremental innovation, and how they alter the NPD process.
2.8	Summary of Chapter 2 and the major contributors for this study.

2.2 – The NPD process

"The New Product Development process is essentially a formal blueprint, roadmap, and template or thought process for driving a new product project from the idea stage through to market launch and beyond" (Cooper, 1994).

One of the most common NPD processes is the stage-gate system developed by Robert Cooper (1990). Different from the cumbersome and time-consuming NASA-based *Phased Review Process* of the 1960s it focuses on business risks[6] along with technical/engineering aspects of the product project (Cooper, 1994). It consists of five stages (workstation) that are opened by five gates (checkpoint), at which point a multi-disciplinary team oversees inputs (clearly specified deliverables[7]), a set of exit criteria (items upon which project is judged and potential hurdles), and the output in order for a decision to GO, KILL, HOLD, or RECYCLE to be made (Cooper, 1990) (see Figure 2.1

[6] Considerable homework is done on market research, competitive analysis, concept tests, manufacturing assessments, and the business/financial analysis. A stronger market orientation is another integral facet of this product development process (Cooper, 1994).
[7] Examples of inputs include results of the user "needs and wants" market study, competitive analysis, detailed technical appraisal, or a financial assessment.

and Appendix II for a 13-step aberration of Cooper's (1990) model adapted by Poolton and Barclay, 2000).

Figures 2.2, 2.3, and 2.4 depict similar-type NPD models of Kumar *et al.* (1994), Ulrich and Eppinger (2000), and Griffin (1997). For the purposes of this research, special attention will be given to the Kumar *et al.* (1994) and Griffin (1997) models. The Kumar *et al.* (1994) model is further elaborated on in Appendix III.

Ulrich and Eppinger (2000) identify separate tasks and responsibilities for Design, Manufacturing and Marketing at each stage of the process (see Appendix IV), however, Cooper's (1990) system emphasizes the cross-functional nature of each stage and gate, restricting any function from controlling the activities of any stage (Cooper, 1994). Cooper's (1994) third generation NPD process introduces four more important facets of NPD, typically categorized under four Fs; fluidity and adaptability[8], fuzzy gates[9], focus of resources and management[10], and flexibility[11] (Cooper, 1994).

Overlapping, skipping or deleting stages is acceptable based on a study by Cooper and Kleinschmidt (1986) where they found that only 2% of 252 new or significantly improved products used every stage of the NPD process[12]. Mahajan and Wind (1992) identified the most frequently used activities of Cooper's (1990) model as seen in Appendix V.

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[8] Activities of the next stage can begin before completing the current stage.
[9] Conditional or situtational decisions are made based on partial information.
[10] Projects for the portfolio are prioritized by initial estimates of market size, possible sales, the potential for profit, and realistic assessments of technical and commercial success (Cooper, 1994).
[11] The amount of change and overlap possible in the process, the need for information, and the amount of uncertainty or risk tolerable.
[12] The most important stages they identified were the initial screening, product development and in-house product testing (Cooper and Kleinschmidt, 1986).

Figure 2.1 – Cooper (1990) Stage-Gate Model

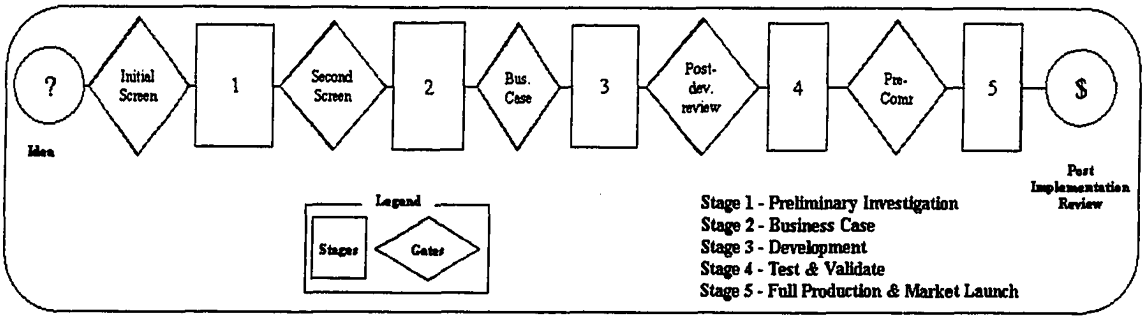


Figure 2.2 – Kumar *et al.* (1994) Innovation Model

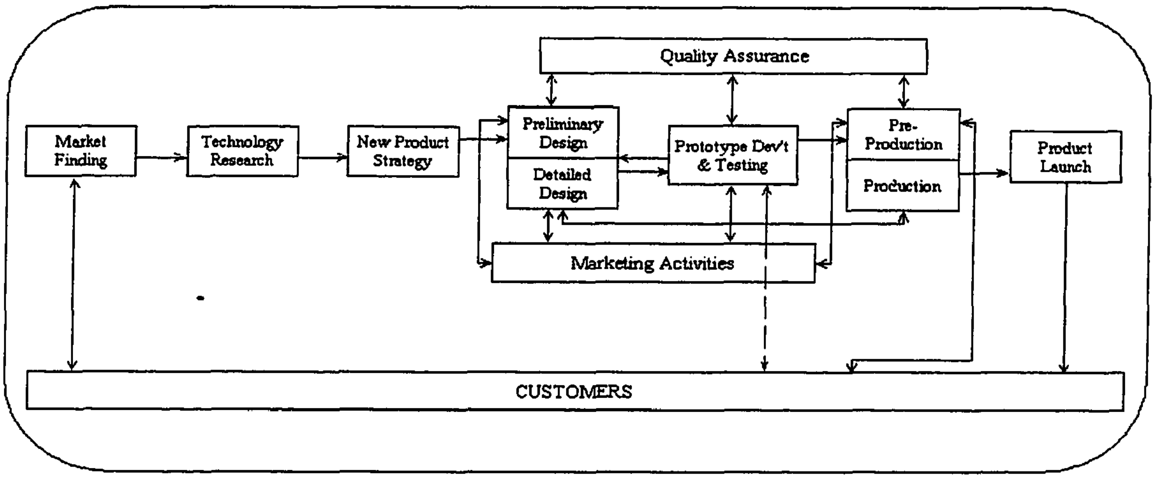


Figure 2.3 – Ulrich and Eppinger (2000) Generic Product Development Process

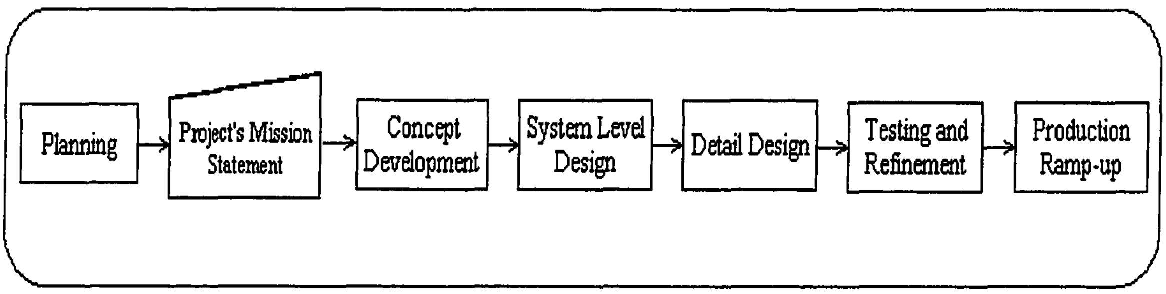
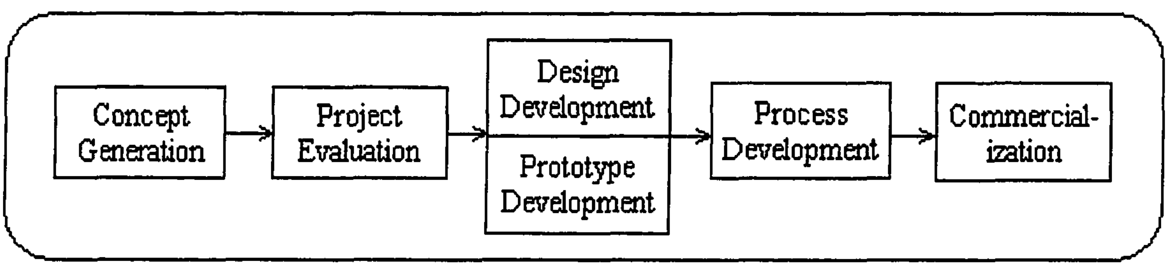


Figure 2.4 – Griffin (1993) Stages of New Product Development Process



The NPD process has received numerous contributions throughout the literature[13] which help prescribe a better performing NPD process. In Table 2.1 below a summary of the major themes and key characteristics emerging from the NPD process is presented.

Table 2.1 – Ingredients of a Well-Performing NPD Process (Bessant and Francis, 1997)

THEME	KEY CHARACTERISTICS
Systematic process for processing new products	Stage-gate model Close monitoring and evaluation at each stage
Early involvement of all relevant functions	Bringing key perspectives into the process early enough to include design and prepare for downstream problems Early detection of problems leads to less rework
Overlapping/parallel working	Concurrent or simultaneous engineering to aid faster development whilst retaining cross-functional involvement
Appropriate project management structures	Choice of structure – e.g. matrix/line/project/heavyweight project management – to suit conditions and task
Cross-functional team working	Involvement of different perspectives, use of team-building approaches to ensure effective team working and develop capabilities in flexible problem-solving.
Advanced support tools	Use of tools – such as CAD, rapid prototyping, computer-supported co-operative work aids (e.g. Lotus Notes) – to assist with quality and speed of development
Learning and continuous improvement	Carrying forward lessons learned, via post-project audits etc. Development of continuous improvement culture

As seen in Table 2.1, overlapping, early involvement, cross-functional teams, support tools, and learning are among the crucial practices that make up CE (Poolton and Barclay, 2000). This research explores the contributions of these components and many others, as practices needed for CE, to successfully influence the NPD process in achieving performance goals (such as cycle time). With these practices, reduction of cycle time is achieved as paralleling of activities within the NPD process is improved

[13] Researchers such as Bessant and Francis, 1997; Barclay and Dann, 2000; Crawford, 1991; Griffin, 1996; Ha and Porteus, 1995; Johne and Snelson, 1988; Krishnan *et al.*, 1997; Kumar *et al.*, 1994; Lilien and Yoon, 1989; Lock and Terwiesch, 1998, Mahajan and Wind, 1992; Maidique and Zirger, 1985; Njissen and Commandeur, 1995; Rothwell, 1992; Spivey *et al.*, 1997; Smith and Reinertsen, 1991; Stalk and Hout, 1990; Thomas, 1993; and Wheelwright and Clark, 1992.

(from product concept generation to product introduction) and interfaces between Manufacturing, Design and Marketing become stronger.

Understanding the benefits of a clear development process is important for this study. A well-defined process reduces the failure rates of new or significantly improved products by securing quality assurance, coordination, planning, management practices, and improvement (Ulrich and Eppinger, 2000).

2.3 – NPD Cycle Time Reduction

"New Product Development Cycle Time is critical because life cycles are shrinking, and obsolescence is occurring more quickly than in the past while competition has intensified" (Griffin, 1997).

In today's world economy, regardless of the industry, organizations are searching for new ways to compete more effectively and efficiently. In their efforts to do so, they are confronted with numerous competitive challenges. It is no longer sufficient to meet the traditional requirements of product cost, performance, quality and dependable delivery. A new significant challenge involves reducing the time required to successfully bring new products to market. Due to the vast amount of product offerings in the market, keeping up with the competition companies means bringing newer products to market faster; product obsolescence occurs so rapidly (Crawford, 1992; Griffin, 1993; Millson *et al.*, 1992; Takeuchi and Nonaka, 1986; and Towner, 1994). Time has become a scarce resource and an economic necessity. Reducing time allows for market share growth by accommodating customers earlier, increasing customer satisfaction, and increasing quality since time requires things be right the first time (McDonough and Barczak, 1991).

Time is an especially important factor of the competitive environment within which Electronic Parts and Component Manufacturing companies operate. Being second to market can often mean lost investment costs and missed market opportunities. With advanced manufacturing technologies and other technological advancements, products are more rapidly becoming obsolete and companies are challenged by the possibility of their customers replacing their products with those of their competitors. With increased globalization, markets are further becoming competitive and those companies that don't achieve speed-to-market often risk decline and even death in their industry.

According to a study by Scott (2000) reduction of cycle time[14] ranked third out of the top 24 issues for product development in high technology (following strategic planning and organizational learning). In a study sponsored by the Product Development and Management Association, it was found that 40% of firms studied reduced their NPD cycle time over five years. Firms such as Honda, Xerox, AT&T, Hallmark, and Chrysler all reduced their cycle time by 50% (Calantone and Di Benedetto, 2000; Griffin 1993; and Trygg 1993) (see Appendix VI).

The importance of shorter product development cycle time is heavily stressed in business research journals[15]. There is an abundance of research on techniques (practices, tools, etc.) that can be used for reducing the product development cycle time (Griffin, 1997). What remains unclear, however, is how much improvement these techniques, tools or practices, actually make to reducing the time it takes to commercialize a product. In order to study this, a proper set of metrics is needed when measuring product

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[14] In Scott's (2000) study reduction of cycle time included issues such as limitations of cycle time reduction benchmarks, making Concurrent Engineering work, and using the extra time to permit product development to start later on (in order to take advantage of new technologies and customer needs).

[15] Bird *et al.*, 1990; Cooper and Kleinschimdt, 1994; Cordero, 1991; Crawford, 1992; Dumaine, 1991; Emmanuelides, 1991; Griffin, 1993; Griffin, 1997; Gupta *et al.*, 1992; Kessler *et al.*, 2000; Kessler and Chakrabarti, 1999; Lynn *et al.*, 1999; McDonough, 1993; McDonough and Barczak, 1991; Mullins and Sutherland, 1998; Njissen *et al.*, 1995; Rosenthal *et al.*, 1991, Uttal, 1987. Gerwin and Barrowman (2001) list the studies that looked at Development Time as a performance goal.

development cycle time (Griffin, 1993). The following section explains different measures that are helpful for constructing measures of time.

2.3.1 – Cycle time

2.3.1.1 – Measures of Cycle Time

If not defined properly, cycle time can be analyzed upon many different meanings. Rusinko (1997) defines time as the "degree of success in meeting a project time goal". McDonough (1993) measures the time it takes for products to be developed by assessing how close the project is to meeting its time goal: ahead or behind by a certain percentage, or on time. Cooper and Kleinschmidt (1994) Chryssochoidis and Wong (2000) also measure time by how well the project stays on schedule. De Toni and Meneghetti (2000) focus on external cycle time (i.e. changes in the time that products and services become visible to customers), or internal cycle time (i.e. changes to the design and manufacturing processes that allow development activities to occur more rapidly). Griffin (1993) divided cycle time into: Time-to-Market, Concept-to-Customer and Development Time.

Time can also be identified by the NPD stages it encompasses, such as the "cycle time from conception to production", whereby the understanding of time depends on clear definitions of conception and production. The goal of measuring time becomes even more elusive when the start of NPD stages is "fuzzy" or ill-defined. This is particularly the case with the front-end stage[16] of the NPD cycle, where the start of

[16] The front-end stage, usually concept development is made up of the following front-end activities: identifying customer needs, establishing target specifications, generating product concepts, selecting product concepts, testing product concepts, setting final specification, and planning downstream development (Ulrich and Eppinger, 2000).

concept development is much less clear than the start of detailed design and prototype development (Cooper and Kleinschmidt, 1994; and Griffin, 1993).

The interesting aspect of the "fuzzy" front-end is that it could be the "bargain basement of cycle-time reduction opportunities... [it has] the least expensive opportunities [for achieving] large improvements in Time-to-Market" (Smith and Reinertsen, 1998). Kumar *et al.* (1994) also found that reducing NPD cycle by making the right decisions on product features, performance dimensions, and product costs early on is important. Thus it becomes necessary to determine ways of reducing the time that the front end stages add to NPD cycle time. This would mean using time variables that measure different stages of the NPD process.

In order to be able to measure the actual steps of the development process, Griffin (1993, 1997) uses project timing, which "chronicle[s] the dates when various phases of development [begin]". As mentioned already, Griffin measured NPD cycle time, in terms of Time-to-Market, Concept-to-Customer and Development Time.

This research will investigate the CE practices[17] that reduce NPD cycle time, in terms of the Time-to-Market, Concept-to-Customer, and Development Time. Each one of the time variables begin with different stages of the NPD process, but the series of activities of interest end just before the product launch stage begins, which Kumar *et al.* (1994) call the production stage of the NPD process, for the purpose of treating time as an internal variable. For the purposes of this research further discussion of the contributions of Griffin's time measures is essential and is available in Section 2.3.1.3.

[17] CE is defined as "the earliest possible integration of the overall company's knowledge, resources, and experience in design, development, marketing, manufacturing, and sales into creating successful new products, with high quality and low cost, while meeting customer expectations. The most important result of applying CE is the shortening of the product concept, design and development process from a serial to a parallel one" (Shina, 1991).

2.3.1.2 – Comparison of Models

It has been established that in order to measure NPD cycle time, the stages of the NPD process must be defined. The variety of NPD models existing in the literature is abundant. It is therefore necessary to find one that is most applicable to the situation at hand. As illustrated in Section 2.2, Cooper (1990), Griffin (1993) and Kumar *et al.* (1994) each constructed unique NPD models. Through comparison it is to be determined which one is most appropriate for this research.

Comparing Griffin (1993) and Cooper (1990)[18], for the purposes of their use in this research, Griffin's (1993) model of the stages of product development is more suitable than Cooper's (1990) stage-gate model mainly because of its simplicity. According to Cooper (1990) "corporations are increasingly looking to stage-gate models as effective tools to manage, direct, and control their product-innovation efforts". The underlying concept of the model is that each stage should begin only once the output of the previous stage has been given approval at the gate that separates the two stages. Smith and Reinertsen (1998), however, recently point out that although "users of stage-gate processes, and Cooper himself, are working to streamline the stage-gate process, it remains primarily oriented toward control rather than speed… [according to the situation] you determine how much emphasis to place on stages and gates".

Griffin, on the other hand, excludes many components included by Cooper (e.g. the different gates), which de-emphasizes specific activities of the NPD process, and highlights major steps of the process. This is beneficial for this research since the

[18] Both Cooper (1990) and Griffin (1993) both encompassed the following activities in their models: preliminary investigation (i.e. generating and screening ideas, and identifying target markets); business case (i.e. concept and specifications development); detailed design and prototype development, process design and pilot plant trails; test and validate, full production, and product launch.

intended scope is to measure the time taken for a product to go from one point of the NPD process to another end point (such as production). It is not the objective of this research to measure the specific time for each individual activity within NPD process. Another benefit for this research is the simplicity that Griffin's method provides for the survey respondents, as it eliminates unneeded steps. The argument follows that Griffin's (1993) model is more compelling for this research; and with contributions from Kumar *et al.* (1994) can be further completed.

Between Griffin's (1993) model and the Kumar et al. (1994) model, Griffin's model lacks in addressing the issue of collaboration between different departments (e.g. marketing, manufacturing and design) throughout the stages of the NPD process. Emphasis is placed on stages that are dominated by a particular function. Kumar et al. (1993), however, draw light upon stages of the NPD process that require collaboration. This notion inter-relates with CE, a key element of this research.

In interviewing 18 medium-sized electronic hardware firms and asking respondents to describe the stages of the NPD process, the Kumar *et al.* (1994) model is also able to provide more detailed explanations on the activities that take place within each stage of the NPD process, particularly for firms in the Canadian electronics and telecommunications industry. For the purposes of this research, this is an additional contribution since that industry resembles the Electronic Parts and Components industry, which will be focused on in this research.

Having considered the merits of Griffin (1993) and Kumar *et al.* (1994), the outcome is to apply Griffin's (1993) model, where time is measured in terms of three time variables (i.e. Time-to-Market, Concept-to-Customer, and Development Time), and adapt it with the input regarding the NPD stages from Kumar *et al.* (1994). The following Section 2.3.1.3 explains how and what parts of the two models were combined together, and the final output to be used for this research.

2.3.1.3 – Relevance of the Griffin and Kumar Models for this Research

Both Kumar *et al.* and Griffin define the tasks and criteria needed for determining a start date for each stage of the product development process. In combining their models, it becomes possible to come up with appropriate NPD stages that will mark the beginning and end points of NPD cycle time for this research; where NPD cycle time will be measured in terms of the three time variables taken from Griffin's model.

In Table 2.2, the stages of the NPD process as identified by Griffin are presented. It considers segmentation and identification of the market and customers, figuring out the right product, and taking the product through production. It also includes indicators for the beginning points of each stage. Zirger and Hartley (1994) refer to this time metric as "benchmark[ing] Development Time at various phases of project completion". Knowing the stages of the process instead of just the start dates and end date of the NPD process is important for understanding the link between the adoption of CE practices and the reduction of NPD cycle time measured in terms of Time-to-Market, Concept-to-Customer, and Development Time. Each time variable is made up of certain stages of the NPD process.

Table 2.2 – Start Dates for NPD Tasks (Griffin, 1993)

Stage	Tasks	Start Date
0	Concept generation – idea for product surfaces	First planning meeting First customer request Date of competitive entry
1	Project evaluation – product strategy and target market approved and development on specifications can begin	Approval of strategy/idea First marketing meeting
2	Detailed design and prototype development – spending of research and development on physically developing the product begins	First development team meeting Product specification approval
3	Manufacturing development, process designs, and pilot plant trials – documentation of process development begins	First manufacturing meeting First pilot trial
4	Commercialization - production trials begin	First manufacturing trial

Griffin's (1993) stages, in Table 2.2, are adapted by including those proven to be used in Electronic Manufacturing firms by Kumar *et al.* (1994). Table 2.3, shows the different stages of the NPD process as well as the starting and ending activities. In order to clarify the ending activities, individual activities within the concept development stage of the NPD process as delineated by Ulrich and Eppinger[19] (2000) and depicted in Section 2.2, have been included in the table below. Identifying development based activities in the NPD stages to be used for this research will appear applicable upon review of the design/development oriented CE practices found in Section 2.5.

[19] Ulrich and Eppinger (2000) include the following specific activities as part of the concept development stage of the NPD process as they define it: identification of customer needs, identification of product specifications, concept generation, concept selection, concept testing, and product architecture.

Table 2.3 – NPD Stages and Start Dates in Electronic Manufacturing Firms

Stage	Tasks	Starting Activities	Ending Activities
0	Market Finding[20] – Decision to either expand or maintain market share depending on market conditions is made. Technology research is also included, whereby technical and commercial feasibility of ideas is also assessed.	First planning meeting occurs. or First customer request gathered.	Market requirements and customer needs are identified. Basic product requirements[21] are identified. Several concepts are generated.
1	New Product Strategy – Feasibility and strategic role of product in the market is assessed.	First brain-storming session of business case analysis.	Business Case and Competitive Analysis have been approved by top management.
2	Detailed Design and Prototype Development – Physical development of the product begins	First drawing of potential final product.	Concept is selected and Product Architecture[22] is determined.
3	Pre-Production – Manufacturing development, process designs, and pilot plant trials begin	First drawing of process development for the final product.	Pilot plant trial is proven to be successful and the product is sent to the production line.
4	Production – Manufacturing of the final product begins.	First manufacturing run of the final product.	After the pilot run the product is tested for full-scale production to start.

The stages described above become easier to measure as the development process moves forward. The earliest stages are the most difficult to uncover. Stages 0 and 1 are usually estimates kept informally with marketing or planning groups. The transition from stage 0 to stage 1 is especially fuzzy (general uncertainties of start dates). Conversely,

[20] 56% of firms studied by Kumar *et al.* (1994) claim market finding begins the NPD process.
[21] In the case of radical innovations for which customers do not have any requirements since the product is so new, firm sets the requirements that they believe will benefit the market.
[22] According to Ulrich and Eppinger (2000) product architecture (functional and physical elements of a product and their interaction) can be defined within two different stages depending on the newness of the product. If the product is an incremental innovation, product architecture occurs at the same time as product concept. Looking at the stages in Table 2.3, it would be partly included in stage 0. Where the product is a radical innovation, product architecture is not known until the design stages such as in stage 2 of Table 2.3.

Stages 2, 3 and 4, are usually recorded in logbooks kept by design/development or manufacturing (Griffin 1993, 1997).

Now that the stages have been identified, the time variables are defined in Table 2.4, each beginning with a different NPD stage taken from Table 2.3, as previously seen.

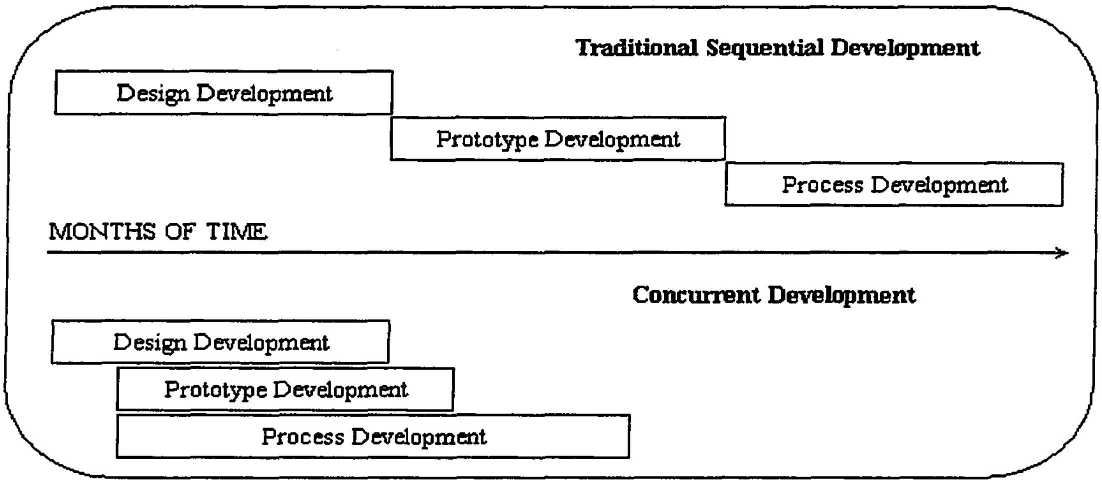
Table 2.4 – Phase Timing Variables (adapted from Griffin, 1993)

TIME VARIABLE	DEFINITION	MEASURES
Time-to-Market	Stage 0 through production	Firm's ability to identify a market opportunity and come up with a suitable product for the customers in that market
Concept-to-Customer	Stage 1 through production	How difficult it is to figure out the right product
Development Time	Stage 2 through production	How efficiently a product goes through production

The problem with Griffin's NPD process and hence her measure of time, however, is similar to that inherent in many other NPD models; Griffin does not account for the fact that the stages of NPD do not always occur sequentially. The Figure 2.5, on the other hand, reflects the overlapping nature of various stages.

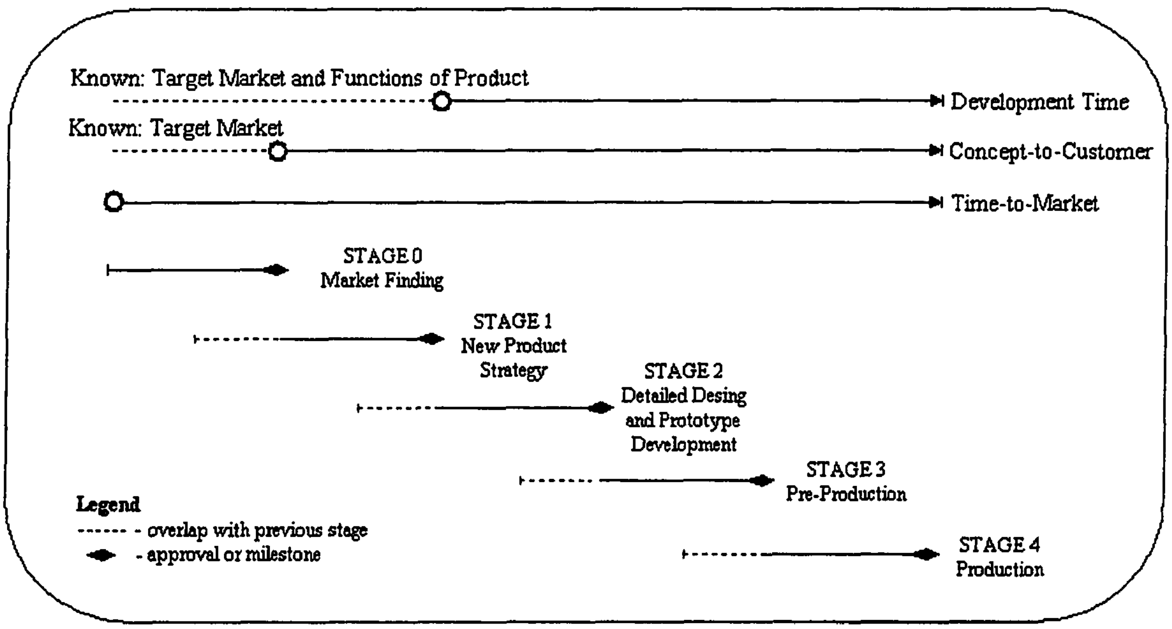
Different functional departments all play important roles in developing the product and their involvement does not always commence after another department completes its role. Overlapping or concurrent development, often referred to as CE, has become a dominant feature of NPD. The most important aim for applying CE is "shortening of the product concept, design and development process from a serial to a parallel one" (Shina, 1991). Section 2.4 discusses overlapping through the Integrated Product Development (IPD). Essentially, the concept to be grasped is depicted in Figure 2.6 (Mabert *et al.*, 1992).

Figure 2.5 – Mechanism for Product Development



Considering this problem, Griffin's (1993) model can be taken one step further for the purposes of meeting the objective of this research; addressing the CE practices that reduce NPD cycle time in terms of Time-to-Market, Concept-to-Customer Time, and Development Time, whereby each time variable begins with a different NPD stage and the stages overlap. Figure 2.5 illustrates how time and the NPD stages coincide:

Figure 2.6 – Time Metrics for NPD stages



2.3.2 – Reduction of NPD cycle time

In business literature NPD cycle time has been labeled as a crucial strategic area for determining the success or failure of the development endeavors of a firm in a time-sensitive industry. Major subject areas found in the literature regarding this topic encompass: the factors or practices that influence the reduction of NPD cycle time, the effectiveness of overlapping activities for reducing NPD cycle time, the measurement of NPD cycle time, and the implications of NPD cycle time reduction. These topics have been explored thoroughly by various researchers, and their works are included in Appendix VII[23].

The strategic importance of cycle time reduction clearly translates into the need to find appropriate techniques for reducing NPD cycle time. This research focuses on one technique in particular for NPD cycle time reduction. It is a product development technique that involves employing practices of CE in order to change the traditional process of developing products through overlapping or concurrent processing of NPD activities. Whether or not the adoption of CE practices lead to a reduction in cycle time measured in terms of Time-to-Market, Concept-to-Customer Time, and Development Time is to be investigated. CE and its practices are further elaborated on in Section 2.5.

2.3.3 – The Implications of Reducing NPD Cycle Time

The success of NPD depends upon a number of different performance measures. These goals can be grouped into three dimensions: time-related, efficiency-related, and quality-related (Griffin and Page, 1993). There are always tradeoffs, however, when focusing on any one of the three performance dimensions in isolation of the others.

[23] Also provided in the table are the industries studied, the sample size, and the statistical techniques used to analyze their data. Each article has been grouped according to the major subject area that it addresses.

Speed is critical, but fast development of an inferior product or of a superb product coupled with extremely unproductive use of organizational resources may not yield the desired results (Lilien and Yoon, 1990). Crawford (1992) identified five major risks of focusing on reducing NPD cycle time: focusing on quick innovation at the expense of breakthroughs; sacrificing necessary information-finding steps for the sake of time; "people costs" of managing cross-functional teams; constrained innovation due to time budgets; and teams consuming large amounts of firm resources.

Despite these findings, however, several product development studies report positive correlations between performance dimensions such as speed and productivity or speed and quality (Clark and Fujimoto, 1991; and Stalk and Hout, 1990). This paradox may be attributed to the fact that practices contributing to speed simultaneously contribute to quality and productivity. Furthermore, the penalties for being late to market in growing businesses can far outweigh other costs.

Cycle time reduction, is not only important for introducing new products sooner, but it permits for a later start on product development. This allows the firm to make use of the newest technologies and realize the most current customer needs, thereby increasing product performance and quality (Scott, 2000).

When trying to achieve cycle time reduction, focusing on time and putting aside other performance goals may be crucial. "If Development Time is not included as a performance measure, time will become subordinate to other product goals such as cost, quality and product performance" (Zirger and Hartley, 1994). Simply setting time as an explicit goal, can affect the reduction of product development cycle time (Zirger and Hartely, 1994; Rosenthal and Tatikonda, 1993). McDonough III (1993) asked project leaders how important product development cycle time reduction was in producing the product, and on a scale from 1 to 7, projects receiving a score of less than 5 were omitted from the study.

This research does not focus on other performance dimensions such as quality, productivity or cost, but it is interesting to note that reducing time does not necessarily result in a negative impact upon other product performance dimensions. This research focuses on projects where reducing cycle time is an intended goal and where other performance dimensions, such as market success, have not been sacrificed for the fulfillment of cycle time goals.

2.4 – Integrating the NPD Process

"Integrated Product Development (IPD), also referred to as concurrent engineering, is one of the most significant contemporary trends in the management the of new product development (NPD). In fact IPD has become the paradigm for NPD" (Gerwin and Barrowman, 2001).

With a New Product Development project there are a number of goals in which NPD managers may choose to pursue. As discussed previously examples of NPD goals include cost, quality, time, and product performance. No matter which goal NPD managers decide to succeed in, consideration of upstream decision making in the development of the product is a growing necessity. Traditionally NPD was performed as a series of sequential activities, whereby the succeeding activities commenced once the preceding activity was terminated (refer to Section 2.2). Today, however, NPD, often known as Integrated Product Development (IPD) integrates product and process design by interfacing the different business functions with one another as well as with customers/suppliers.

A key component of IPD is strong emphasis on the overlapping of the product development process (Te and Loch, 1999), and "reciprocal interdependence"[24] (Hauptman and Hirji, 1999). Clark and Fujimoto (1997) found that overlapping is a powerful tool for achieving NPD goals, especially for reducing NPD cycle time. Integration and coordination mechanisms are at the heart of IPD (Hauptman and Hirji, 1999). One way of achieving integration is "through interoperability, product data management, process management, and decision support" (Gerwin and Barrowman, 2001). It is supported by improving horizontal communications, establishing clear lines of responsibility, delegating authority and instituting clear interfaces with suppliers and customers. IPD uses a "systematic method for acquiring and analyzing information about capabilities and limitations of the manufacturing process" and allows for alterations in the parameters of product and process design in order to enhance performance (Abdalla, 1999).

A project that uses IPD, focuses on "Development Time, development cost, product quality, product cost, and overall product performance" as intermediary objectives that lead to the improvement of ultimate performance measures such as market share and return on investment (Gerwin and Barrownman, 2001).

2.4.1 – Concurrent Engineering (CE)

While some liken CE to be yet another name for NPD or IPD (Nellore and Balachandra, 2001), others acknowledge it to be a mechanism for achieving IPD or a manifestation of IPD. Whatever the case may be this research is interested in how CE can be used as an integrating mechanism for reducing NPD cycle time.

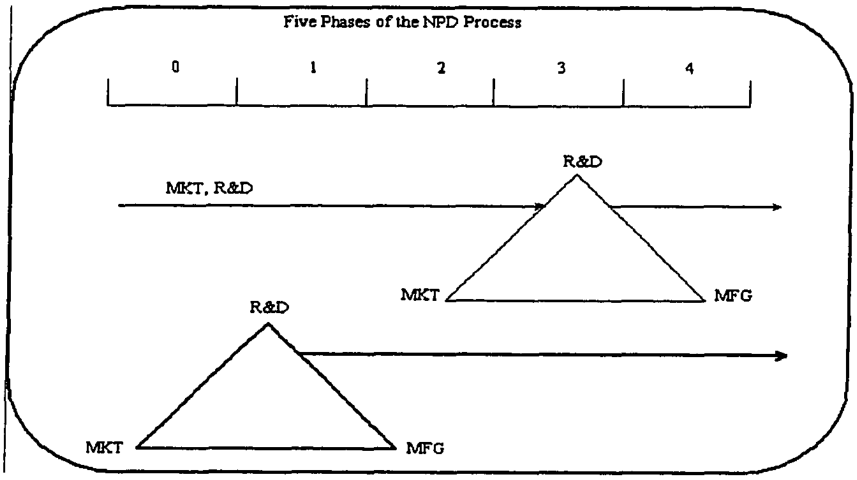
[24] Reciprocal interdependence was used by Thompson (1967) to characterize the relationship between the frequency and intensity of information sharing and the design of new products and processes.

CE can be a technology, philosophy or strategy that requires collaborative cross-functional work and integrates all elements of the product life cycle from idea generation to market launch[25] (Duffy and Salvendy, 1998, Linton *et al.*, 1991, and Trygg, 1993). CE is typically manifested through the early involvement of multiple functions working together as a team and sharing information. The objective is for all members to have influence in product design, process and manufacturing decisions (Hull *et al.*, 1996, and Koufteros *et al.*, 2001) as early as possible in the beginning stages of development. The most significant change CE brings is manufacturing's participation in generating the product concept and investigating market requirements. It is also involved in product planning and R&D (Gerwin, 1993).

In Figure 2.7, Gerwin (1993) depicts CE's redefinition of manufacturing involvement with regards to the stages of NPD. The second triangle contrasts manufacturing's involvement in the front-end of the process with its involvement in the latter stages of the process. No function ever becomes responsible for all activities that occur in each stage, but with CE each one has a vested interest in being present in the decision making at earlier points, as they will determine how input from the others will be used to do their own tasks (Gerwin, 1993). Each function coordinates with the other in order to consider feasible alternatives, instead of using one another as buffers against demands. This is an important aspect that differentiates CE from traditional NPD.

[25] This includes factors such as product functionality, manufacturing, assembly, testing, maintenance, reliability, cost, and quality.

Figure 2.7 – Changes in the NPD Process (Gerwin, 1993)



Linton *et al.* (1991) likens the traditional sequential NPD process to an assembly line. In the assembly line strategy, any unsuccessful event can pre-empt the success of succeeding events. Without integrating the product development activities there can be no room for interaction between the stages. There is also random division of tasks without any coordination between them. The final result is a developed product that is dependent upon the best performing event within the assembly line, as opposed to the contribution of the total sum of the activities occurring intertwined with one another. This notion of sequential NPD was earlier touched upon in relation to Griffin's NPD process and provides yet another justification for emphasizing overlap of stages in CE.

The major differences of the perspectives relating to the traditional sequential NPD process (i.e. sequential engineering process) and the CE process[26] (Clark and Fujimoto, 1991, Krishnan, 1996) are summarized in Table 2.5. The basic principles of CE are available in Appendix VIII.

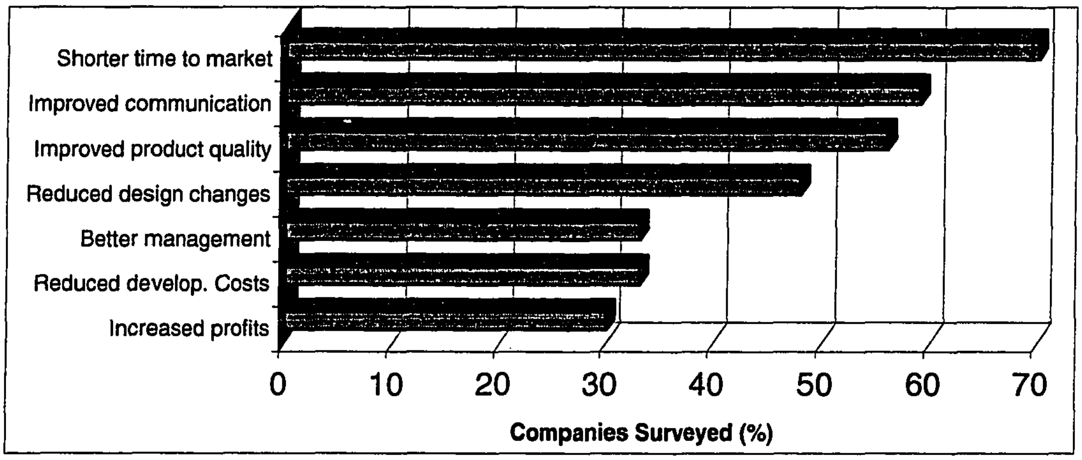
[26] According to Ganapathy and Goh (1997) CE is "characterized by a combination of six fundamental elements that differentiate it from traditional product development". These six elements include cross-functional teams, concurrent product realization process activities, incremental sharing and use of information, integrated project management, early and continual supplier involvement, and early and continual customer focus.

Table 2.5 – Sequential NPD Process versus Concurrent Engineering

Differing Elements	Sequential NPD Process	Concurrent Engineering
Richness of Information	Sparse documents, computer network	Face-to-face
Frequency of Information	Product information available in one-shot batch at the finish of the generating phase	Pieces of information exchanged many times, on-line, intensive, and integrated problem solving
Direction of Communication	One way monologue	Two way dialogue and feedback
Timing of Information Flow	No intermediate points of information sharing	Early information is shared from the preliminary stages

The essence of CE, however, is not only the concurrency of activities and the effort of cooperative multifunctional teams, but also improving profitability and competitiveness of the final product right from the beginning (Abdalla, 1999). The Figure 2.8 indicates the results of a study executed by Abdalla (1999) due to having implemented CE. It demonstrates the use of CE as a "competitive strategy attempting to simultaneously achieve a portfolio of benefits in time, money and novelty" (Hull *et al.*, 1996).

Figure 2.8 – Benefits of Implementing CE



For the purposes of this research the distinction between IPD, NPD and CE will not be further addressed; focus will be on the practices of CE that permit integration of product development activities. In addition, this research studies CE as a strategy for achieving only of the many performance measures, that is reduction of NPD cycle time.

2.4.2 – Definition of Concurrent Engineering

There are so many different definitions used for CE, IPD and NPD, all equally valid in their own way, that it can become confusing as to which one is the most appropriate for a particular study. For the purposes of studying the relationship between CE practices and the reduction of NPD cycle time (measured in terms of three time variables) and moderated by the type innovation, the appropriate definition is provided.

> *Concurrent Engineering is an integrated multi-disciplinary approach to product development. Representatives from different functional departments as well as customers/suppliers collaborate with one another to communicate partial information about product and process design and manufacturing and marketing decisions. They begin sharing from the point of generating the product idea to putting the product on the market. Everyone focuses on meeting commonly shared product performance goals. The main purpose of applying CE is to shorten the time needed for the NPD process, by overlapping concept generation, design, and development, whenever appropriate. CE uses a combination of people practices, process practices, formal methods, and tool and techniques.*

2.5 – Concurrent Engineering Practices

As mentioned in Section 2.3.2, the focus of this research is on CE as an effective product development technique for reducing the time required to bring new products successfully to the market. It shortens product Development Time by "concurrently designing both the product and downstream production and support processes in the early stages of design" (King and Majchrzak, 1996). Section 2.4.2 pointed out that it includes a number of practices employed to facilitate its goals.

Poolton and Barclay (2000) categorized CE practices as either "soft activities or "hard activities". The soft ones could be further subcategorized under people and process, and the hard ones under tools and techniques and formal methods. These practices are key to CE. Although, this research will not dwell on the "softness" or "hardness" of the practices, it is appealing to point out this categorization as the literature is directed more towards the hard practices when researching CE.

Table 2.6 – Concurrent Engineering Practices (Poolton and Barclay, 2000)

PEOPLE	PROCESS
Cross-Functional Teams (CFT) Team Leadership Team Development Reward and Recognition Co-location	Project Management Formal NPD procedures Customer/Supplier Integration Formal Team Briefings Organizational Redesign
TOOLS AND TECHNIQUES	**FORMAL METHODS**
Computers/Networks Computer Aided Design/Manufacturing Simulation	Quality Function Deployment (QFD) Design of Experiments (DOE) Design for Manufacturability (DFM) Failure Mode and Effects Analysis (FMEA)

It is important to keep in mind that not all companies implement the same practices. According to Poolton and Barclay (2000) companies sometimes rely on their gut feel as to which practices they should implement in the concurrent engineering environment. Portioli-Staudacher *et al.* (2003) have also stated that not all companies use the same practices and that there is variations as to which ones they believe to be most appropriate for the type of product they are developing. One purpose of this research is to investigate which of the following CE practices are frequently used for facilitating the reduction of time in the new product development process.

2.5.1 – People Practices

Cross Functional Teams (CFT) typically include representative members from marketing, design, manufacturing, purchasing, service, customers/suppliers, who collaborate during the NPD process in order to ensure that the needs and desires of customers are met, and manufacturing capabilities are considered (Trygg, 1993;

Ganapathy and Goh, 1997). "There are many different varieties of CFTs, including planning teams, and product development teams, quality teams, process improvement teams, and product development teams" (Denison *et al.*, 1996). They provide an avenue for members to express concerns, capture iterative learning and make decisions at lower levels of the organizational hierarchy (Damanpour, 1991; Denison *et al.*, 1996). Some experts consider them as one of the most effective ways to cut through the barriers to a good design (Whitney, 1988). By communicating continuously, members develop an understanding of the constraints relating to the project and their own function while sharing the resources and experiences needed for the product to come to life. Lateral communications and coordination efforts towards a common goal are two basic features of CFT in the NPD environment (Brown and Karagozoglu, 1993). The CFT is responsible for generating a concept for a product and making the product come to life (Ganapathy and Goh, 1997).

According to a study done by Henke *et al.* (1993) four benefits of CFTs include: the ability of the team to function across vertical lines of authority and undermine hierarchical structures, the decentralization of decision-making, reduced overload of information at higher levels, and greater potential for higher quality decisions. The CFT is also expected to "reduce cycle time, create knowledge, and disseminate organizational learning (Denison *et al.*, 1996). According to Donovan (1994) it is "people who get new products to market fast".

Of the practices they examined, Karagozoglu and Brown found CFTs to be the most highly used practice when developing new or significantly improved products. According to Portioli-Staudacher *et al.* (2003) CFTs are the distinguishing feature of CE.

Their research also found the CFT to be among the most frequently used practice for Italian and even more so for Belgium companies. Allen (1997) stated that cross-functional teams are frequently relied upon, because CE requires that several activities be fulfilled simultaneously and thus a variety of skills be present. Maylor (1997) also found use of CFT to rank after supplier involvement and project management. Winner *et al.* (1988) found this practice to be the most frequently used practice followed by involvement of key suppliers and computers/networks.

Team Development includes investing in education, training, and experience, in order to assure the depth and quality of the skills, and the capabilities of team members. Education in joint product-process design principles, and training in specific methods and procedures, provide team members with the tools needed to solve specific types of problems quickly as they arise (Wheelwright and Clark, 1992). Training the team to work with other members is also essential for developing the NPD team.

By having some understanding of the different roles and responsibilities of the different members, the team is better able to effectively operate through the forming and storming stages that group work typically entails (Smith and Reinertsen, 1998). Abdalla (1999) found that those companies implementing CE also focused on team building skills. Team development also includes CE training that imparts the necessary CE skills (e.g. team problem solving abilities, cross-functional communication, computer integration) to participants through formal workshops, courses and programs (Hull, Collins, and Liker, 1996). Barclay and Dann (2000) posit that such approaches are frequently used by companies to facilitate the process of undergoing NPD activities and improve internal efficiencies.

Team Leadership refers to the degree to which teams are autonomous enough to make their own decisions without too much interference from the functional managers (Gupta and Wilemon, 1990). Empowering the team is instrumental for team autonomy, decision-making authority, and responsibility over the project. Empowerment is defined as the "capability to make a difference in the attainment of individual, team, and organizational goals" (Mohrman *et al.*, 1995). The team is given the authority and capability to make decisions without having to push them up to a higher level where centralized decision-making takes place (Zirger and Hartley, 1994). With empowerment it is essential that the team knows what direction they are going in (i.e. matching personal objectives with organizational ones) and are equipped with the proper resources, knowledge, skills, experiences and organizational support needed to accomplish their tasks. Team leadership is further supported by the organization through performance management systems, strong support systems, management structures and roles, and thoughtful team design (Mohrman *et al.*, 1995).

Four dominant team structures describe the possibilities for team leadership in the product development organization; functional team structure[27], lightweight[28], heavyweight[29], and autonomous[30]. Team leadership would be highest with the autonomous team structure since senior managers delegate complete responsibility for the project to the project leader and designate members of the team (Clark and Wheelwright, 1992). With team leadership/autonomy, the inherent values and benefits of the team are further pronounced (Henke *et al.*, 1993). Gerwin and Moffat (1997) confirm that "team autonomy is an essential characteristic of cross-functional teams engaged in concurrent engineering". With respect to the reduction of cycle time, Zirger and Hartley (1994) clearly identify empowerment and team leadership as a means of reducing cycle time.

Recognizing and rewarding are significant drivers for enhancing the project performance. As mentioned in Section 2.4, IPD heavily depends upon integration and coordination mechanisms (Hauptman and Hirji, 1999). Rewards are an important integrating mechanism for teams. Rewards and recognition work best to increase the

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[27] People are divided into groups based on disciplines, and report to a sub-functional manager and a senior functional manager. Each function addresses certain specifications that are agreed upon by all functions at the beginning of the project. The project moves sequentially from one function to another once each function has finished its own work. The problem with this form is that no one is directly responsible for the outcomes of the project (Clark and Wheelwright, 1992).

[28] Team members represented by a liaison person who represents the team members as they reside in their own functional groups. Liaisons work with a "lightweight project manager" who coordinates the activities of the functional groups. This provides a bit more communication and coordination for the project than the functional team structure, however, power still resides in the functional groups making it difficult to attain project prioritization (Clark and Wheelwright, 1992).

[29] Heavyweight leader is a "project manager [who] has direct access to and responsibility for the work of all those involved in the project... they have expertise and experience, and significant organizational clout... they have primary influence over the people", however they do not determine the contributions of the individual team members. With the heavyweight leader in the autonomous team structure, the responsibility of the project leader is extended to include the performance evaluations of team members (Clark and Wheelwright, 1992).

[30] This form provides the heavyweight team leader with the greatest amount of control over resources contributed towards the project by the functional groups. Team members are "formally assigned, dedicated, and co-located to the project team". The team is directly responsible and accountable for the results of the project. It requires that senior managers delegate a great deal of responsibility and control to the team and its project leader (Clark and Wheelwright, 1992).

performance of the team when they are based upon the team instead of the individual. Individually based goals (e.g. traditional merit pay system, promotional and incentive programs, and salary increases) induce competition, self-interest and functional achievements, rather than cooperation and teamwork (Zirger and Hartley, 1994). According to Mohrman *et al.* (1992) team based reward practices include skill-based pay plans, team bonus systems (such as special team awards and bonus pool), profit sharing, and gain-sharing.

Non-monetary rewards should also function to recognize the team through team award dinners, plaques, or merchandise (see Appendix IX). Recognition is sometimes as significant as tangible rewards. Thamhain and Wilemon (1987) found that through image building and project objectives, management could build a "priority image" for a project. A project that appears interesting, important to the organization, highly visible, and potentially rewarding, is one that can motivate high-quality people and create high-performing cross-functional teams (Thamhain and Wilemon, 1987).

What also makes rewards and recognitions effective for improving team performance, is linking rewards to specific performance goals. Lynn *et al.* (1999) found in their study that goal clarity leads to reduction in NPD cycle time. Organizational behaviour literature has already proven that rewards when matched to goals improves behaviour, hence rewarding teams based on reduction of cycle time will increase the likelihood of this NPD goal being fulfilled. The studies by Kessler and Chakrabarti (1999) and Zirger and Hartley (1994) also confirm that rewards increase the reduction of NPD cycle times.

Co-location involves selecting personnel from different departments and locating them in close proximity[31] to one another. This is done to break down functional barriers by increasing the informal contact and strengthening the bonds between workers (Zirger and Hartley, 1994). Co-location typically involves members from manufacturing, marketing and design who are heavily involved in the decision-making process (Smith and Reinertsen, 1998). If the members are brought within earshot of each other, it is very powerful for improving the communication.

Its main purpose is to enable easier and more frequent interaction between members of different departments; essentially increasing closer communication and collaboration. In a study done by Allen (1997) it was found that at distances past 30 meters the probability of communicating at least once a week was much below 10%. According to King and Majchrzak (1996) increased face-to-face encounters brings more collaborative processes and encourages a higher degree of sincerity, trust and confidence. Barclay and Dann (2000) found that companies interested in increasing their collaboration efforts, used co-location as a means of fostering more effective and higher performing teams. According to Keller (1994), co-location also facilitates the synthesis and transfer of complex information.

Co-location is also known to be a major practice used by many companies such as Chrysler, Black & Decker and Motorola for reducing their new product development cycle times (Smith and Reinertsen, 1998; McDonough III and Kahn, 1997; Mabert *et al.*, 1992). Pawar and Sharifi (1997) found in their study that co-location contributed to the

[31] Kahn and McDonough III (1997) clarify that close proximity can vary considerably. The different functional representatives may be located on the same floor, in the same building, or even in the same city or country. Co-location can take a number of different forms depending on the preferences of the organization. Smith and Reinertsen (1998) apply a very rigid parameter for co-location. Different cubicles spread around the floor do not constitute co-location.

reduction in the number of components used in the end product, and the reduction of design and development lead time.

Despite the research that supports the use of co-location for improved NPD performance, Kahn and McDonough (1997) found co-location to have no significant relationship with NPD performance.

2.5.2 – Process Practices

Project Management is the "planning, organizing, directing, and controlling of company resources for a relatively short-term objective that has been established to complete specific goals and objectives" (Kerzner, 2001). Project management works hand-in-hand with CE. Ainscough and Yazdani (2000) found project management to be the most important factor for integrating activities in the NPD environment and is often "recognized as being a driver of concurrent engineering activities". Research by Ainscough and Yazdani (2000) also shows that project management is associated with quicker development cycle times as it allows for the planning and fulfilment of diverse NPD activities to occur in parallel. Similarly, Barclay and Dann (2000) found project management to be one of the major practices for "driving, monitoring and controlling developments" in the CE environment. Maylor (1997) found that project management was the most frequently used practice for concurrent engineering, followed by the involvement of key suppliers. It is integrated to track activities, manage information, and predict changes that might come up during the life cycle of the product (Ganapathy and Goh, 1997; and Ainscough and Yazdani, 2000).

The typical project management activities involved with CE include: project specification, project budget assessment, technical risk assessment, project planning, and financial risk assessment (Ainscough and Yazdani, 2000)[32]. Two of these activities especially help project management to conveniently manage the complexity of CE tasks. Project specification effectively captures the voice of the customer and clearly documents customer requirements. Project planning includes planning for information that will be made available to downstream activities and allows for project plan to be a living document that involves multiple critical paths[33] and continuous change (Kerzner, 2001; and Ainscough and Yazdani, 2000). Project specification stresses the need for customer/supplier involvement as well as provides the CFT with a clearer idea of what product specifications the members will need to accommodate. Project planning supports the sharing of information which is crucial for overlapping stages. Project management is often associated with quicker product development cycle times since customer requirements are specified from the beginning and activities such as project planning, engineering design, bill of materials, procurement, and production can all occur in-parallel (Kerzner, 2001; and Smith and Reinertsen, 1998).

Despite the support use of project management in CE environments, Portioli-Staudacher *et al.* (2003) found contrary results for project management. Portioli-Staudacher *et al.* (2003), when studying the frequency of use of selected CE practices by Italian and Belgium firms found project management to be closer to the bottom of the list for frequency of use.

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[32] Other key elements of project management include: a commitment to planning; effective risk management; management of creeping scope (changes in the specifications of the project); development of policies, procedures and guidelines; effective project staffing; project sponsorship; wage and salary administration programs, changes in organizational behaviour; and effective problem reporting corrections (Kerzner, 2001).

[33] The critical path is "the longest sequence of activities that leads from a starting point to a finishing point in time" (Stevenson and Hojati, 2001).

Formal NPD Procedures "coupled with project management, are the major means of driving, monitoring, and controlling developments" (Barclay and Dann, 2000). These procedures involve those activities seen in Robert Cooper's (1990) stage-gate model, which includes the main steps that firms go through when developing new products (see Appendix II). Identifying the stages of the NPD process enables firms to formally identify the different activities needed for the development process and the practices that separate the successful projects from the less successful ones (Cooper, 1994). In a study done by Barclay and Dann (2000), concept development, market and business analysis, and organization of internal activities, were critical for the smooth transition from development to production. The two researchers emphasize the need for formal NPD procedures (i.e. the extent to which the rules are written down and followed). They also found in their study that formal NPD procedures along with project management, was the number one factor for integrating activities. Ainscough and Yazdani (2000) confirmed this in their study as they found that "project planning, integrated with formal process, is a powerful methodology for [planning information that is to be released to downstream processes in order to achieve parallel activities]".

Poolton and Barclay (1998) refer to the work that Robert Cooper did in 1975 where he studied 114 case histories of new products and found that the success of the development process depended upon the number of activities involved in the process, and how well the activities were carried out. Then in 1994, Cooper's stage-gate process provided a formal picture of the generic steps a firm goes through when developing new products. Poolton and Barclay (2000) added to Cooper's model by adapting the activities of the process into the 13 steps (see Appendix II) and studied the criticality versus proficiency of each stage (see Appendix XI).

In a study done by Lynn *et al.* (1999) evidence was also found that supported the relationship between formal NPD procedures and NPD cycle time reduction; the NPD process "provide[s] a team with the framework to translate information into action".

Customer/Supplier Integration compliments cross-functional teams by including their representation as part of the team. The motives for including them are akin to those justifying the inclusion of other functional groups. Including them encourages early communication which allows preliminary work to begin earlier on based information acquired in discussions with them. Suppliers can address the restrictions and needs that characterize their work, and customers can specify their requirements right from the beginning without having to go back (Trygg, 1993). It is also important for firms to be aware of the capabilities and capacities of the suppliers before matching them with specifications they will be unable to meet (Balachandra and Nellore, 2001).

Firms can integrate customers at different stages of the NPD process (see Appendix XII). The majority of firms incorporate customers in their NPD at the pre-development phases. It is at these stages that customer involvement yields the highest leverage towards reduced NPD cycle time (Karagozoglu and Brown, 1993). Customer and supplier involvement contribute to significant reduction of delays in the NPD cycle (Karagozoglu and Brown, 1993; Nellore and Balachandra, 2001). "Customer involvement is another aspect typical of the quick-innovating companies...one of the major reasons for delay of development projects are due to late deliveries from suppliers" (Trygg, 1993). "There is considerable evidence that effective CE depends on integrating across the value-added chain of companies" (see Table 2.6 for references regarding customer/supplier involvement) (Liker *et al.,* 1999). Portioli-Staudacher et al. (2003) and Maylor (1997) found that customer/supplier integration is highly used by Belgium, Italian and Swedish firms. Karagozoglu and Brown (1993) also found that customer involvement was among the most frequently used practices that they studied.

Literature also supports customer involvement for being a key factor contributing to NPD success. Supplier integration is actually the greatest differentiator between successful and non-successful product development projects (Ragatz *et al.*, 1997). "Getting the voice of the customer at early steps, as well as suppliers, should save time because all involved outside as well as inside the company are more likely to reach at least preliminary agreements on subsequent steps" (Liker *et al.*, 1999). Kessler and Chakrabarti (1999), explain that firms often integrate customers and suppliers because they can "speed up innovation by adding information expertise regarding new ideas and technologies, providing outsourcing opportunities, and limiting redevelopment by incorporating market trends and user needs directly into the design of products".

Organizational redesign can refer to a number of different aspects. In order to accommodate CE the firm must incorporate some changes to the organization. Organizational variables to be considered include: coordination mechanisms, a team structure approach, management support, functional roles and hierarchy, and reward systems. Redesigning the organization with better coordination mechanisms looks at improving formal linking mechanisms. According to Nadler and Tushman (1987) different types of formal mechanisms used to coordinate the efforts of organizational groups include structural linking mechanisms (e.g. liaison, cross-unit groups, integrator roles, integrator department, and matrix), and management processes (e.g. reward and control systems). A firm must choose the right formal linking mechanism that matches the work-related interdependence of the firm in order to assure that information processing requirements fit with information processing capacities. For the CE environment the most successful organizational structure for NPD is the project team approach (Shina, 1991). This means that the organization must provide teams with the autonomy to make independent decisions, a reward system that supports teams, executive support of CE and cross-functional communication, and equal importance of all functional units. Redesigning the organization might take time at the beginning but usually means time-savings later on as integration and coordination mechanisms are more exact for the needs of the organization. A firm must also choose the best organizational form that meets their concurrent engineering needs. According to Smith and Reinertsen (1998) and Ulrich and Eppinger (2000) the five forms a firm can choose from include: functional, lightweight, balanced, heavyweight, and separate project (see Appendix XIII).

Formal team briefings are essential for any team environment. Communication can take place via post, telephone, fax, video-conferencing, E-mail and sharing electronic databases (Pawar and Sharifi, 1997), but these modes do not ensure that all members of a team understand and are up-to-date regarding the status and pertinent information of the project. According to Denison *et al.* (1996) team members need to be both representatives of their functional authority structures and creative problem-solvers". Formal team briefings are a way of meeting these demands. Formal team briefings should require that all members of the team be present. Sometimes even having the presence of management is effective to confirm the direction of the project. Each member of the team should be provided with whatever necessary information accompanies the briefings and have the opportunity to address any concerns or questions that arise during the briefings. Teams also require information inputs provided by the different functional areas of the organization and other CFT responsible for other components of the final product. Formal team briefings should be called when there are benefits of having the team interact together while receiving the information (Denison *et al.*, 1996).

2.5.3 – Tools and Techniques

Computers/Networks in the CE environment are used for computer integration. Computer integration is "the application of a computer to bridge and connect various computerized systems and connect them into a coherent, integrated whole" (Wallace and Dougherty, 1987). Specific functions can also be integrated, such as computer integrated manufacturing (CIM). CIM is the "use of computer technology to link together all functions related to the manufacture of a product" (Moody, 1990). CIM is an "operating philosophy aiming at greater efficiency across the whole cycle of the product design, manufacturing, and marketing" (Duffy *et al.*, 1995). Other computer integration technologies include: CAD, CAM, computer-supported cooperative work, distributed information systems, group decision support systems, and expert systems (King and Majchrzak, 1996).

Computers/networks are also essential for automating the activities involved with the NPD process. Automation means converting all manual methods and modules to computer processes, thus resulting in cost and time-savings. It uses interoperable tools and tasks, interoperable computing environment, data management, process management, and decision support (Carter and Baker, 1992). Computers/networks help increase the concurrency of design by providing team members with common databases to communicate and share information (Cleetus and Reddy, 1992). Portioli-Staudacher *et al.* (2003) also found that Belgian and Italian firms frequently use information technologies and computers for networking. With computers, "interoperable methods and tasks, an interoperable computing environment, product data management, process management, and decision support capabilities" all become possible (King and Majchrzak, 1996).

Computer Aided Design/Manufacturing are computer-aided techniques that reduce NPD cycle time (Cordero, 1991; Zirger and Hartley, 1994). Some researchers find that the systems reduce the number of hours committed by people doing complex computational and drafting procedures and facilitate cost reductions and quality improvement in the NPD process (Cordero, 1991). They allow a firm to handle a greater amount of information needed for implementing product strategies and learning by facilitating the retention, retrieval, storage and transfer of the technical information (Wheelwright and Clark, 1992; and Zirger and Hartley, 1994). These computer integration techniques allow for the maximization of CE benefits when combined with the right hardware and software as they assist in organizing the NPD process (Chakrabarti *et al.*, 1999; Trygg, 1993). The disadvantage of these systems is that as a standalone they can have a negative impact on performance. They must be used as a medium for communication (Roberston and Allen, 1993).

a) *Computer Aided Design* is a "design software and hardware package which utilizes interactive computer graphics" (Duffy *et al.*, 1995) and quickly transfers information about specifications and other design parameters between the stages with less probabilities of error occurrence (Brown and Karagozoglu, 1993; Mabert *et al.*, 1992; and Millson *et al.*, 1992). Winner *et al.* (1988) found that CAD was frequently used by Swedish firms to support design integration. With CAD, engineers can create a prototype of the product in the computer and using computer-aided engineering they can test the performance of that prototype (Cordero, 1991). CAD also increases the extent of information sharing across intra- and inter-organizational boundaries during the NPD process (Zirger and Hartley, 1994). Wheelwright and Clark (1992) cite Kodak's success in using CAD to reduce the traditional product development process for the Fling camera from seventy weeks to forty weeks. Karagozoglu and Brown (1993) and Liker et al. (1999) research found that computer-aided design systems "dramatically reduce product design time as well as the number of prototypes that must be built" resulting in a speedier NPD process. Zirger and Hartley (1994) and Cordero (1991) also found that computer-aided design and manufacturing systems reduce the need for long computational and drafting procedures, ultimately reducing NPD cycle time.

Despite these findings, there is also research that suggests that computer-aided design slows down the NPD process. Kessler and Chakrabarti (1999) found that managers trying to reduce NPD cycle time were better off to reduce the reliance of computer-aided systems. Trabrizi and Eisenhardt (1993) also found that computer-aided design slows down the process because perhaps the systems were inappropriately implemented, it created delays due to overuse of the system, or were poorly suited for the creation and testing of new designs.

b) Computer-Aided Manufacturing "involves both the planning of how the product is to be manufactured and the actual control of the processes used during its production" (Duffy *et al.*, 1995). CAM links together CAD and automated prototype manufacturing (Kamm, 1987). CAM offers flexible manufacturing systems (FMS), which is a "group of machines that include supervisory computer control, automatic material handling, and robots or other automated processing equipment. [They are] designed to handle intermittent processing requirements and produce a variety of similar products" (Stevenson and Hojati, 2001).

Simulation is "a descriptive technique in which a model of a process is developed and then experiments are conducted on the model to evaluate its behaviour under various conditions" (Stevenson and Hojati, 2001). According to Industry Canada Strategis Website, simulation is "a device, system or computer program that represents certain features of the behaviour of a physical or abstract system". Simulations can be very practical as most simulation packages can run on personal computers and be done without requiring programming. It produces tabular, graphical, and animate forms, which assist with the evaluation of alternatives (Shina, 1991). They do not provide solutions but rather allow decision makers to test solutions on a model that resembles a real process.

The benefit of simulation is that it allows for complex situations to be tested with relative simplicity instead of having to test the model's real-life counterpart (Stevenson and Hojati, 2001). Simulation also saves time as it "correlate[s] the automatic test equipment (ATE) specifications, and create[s] the required ATE inputs for a given design before a prototype is built (Carter and Baker, 1992). When more time is spent in simulation verifying whether the product will function the way it is supposed to and minimizing the number of errors and the impact they have on the final product performance, less time is spent in rework and recycling (Wheelwright and Clark, 1996).

2.5.4 – Formal Methods

Quality Function Deployment (QFD) is a "method designed to help the NPD-project team to identify and interpret the needs and wants of customers. According to Abdalla (1999), companies that implement concurrent engineering also focus on using quality function deployment (and other practices such as team building and total quality management). Winner *et al.* (1988) also found that companies implementing CE frequently use quality function deployment. The aim is to establish the importance of product attributes and transform them into technical requirements" (Njissen and Frambach, 2000), which are carried through each stage of the product development process (Shina, 1991). QFD enhances the planning ability of the organization for communication, documentation, analysis and prioritization involving marketing, R&D, manufacturing, quality, purchasing, sales, and service for a specific project (Shina, 1991). It requires teamwork and organizational commitment.

Its benefits include: quality control of product development, fuller specification of designs, reduction of the number of changes needed for design, and integrating the needs of the customer in the design and production process (Duffy *et al.*, 1995; Trygg, 1993). QFD has been found by many Japanese manufacturing companies to decrease the time needed for a product to go from design to production (Griffin, 1993; and Trygg, 1993). It ensures a systematic focus on the customer requirements during the entire development process that reduces the need for rework or scrap. "QFD aims at securing a high level of effectiveness in the development effort" (Trygg, 1993).

Despite its benefits, not all NPD managers choose to implement quality function deployment. Portioli-Staudacher *et al.* (2003), on the other hand, found that for both Italian and Belgian companies, design for manufacturing was one of the least frequently used practices examined.

Design of Experiments is a technical method used to obtain the optimal settings of a process or characteristic of a product design. It uses screening to determine which of the possible factors should be included for further study, and modeling to further refine the factors found in screening using experimental techniques (Shina, 1991). It supports the reduction of NPD cycle time by minimizing the number of experiments needed for the project. This prevents the team from examining combinations of specifications that are not feasible, and only spending time on the design variables that might actually work. This method also allows for a physical model to be constructed so designers have a better idea of what they are looking at (Ulrich and Eppinger, 2000).

Design for Manufacture "is the integration of product and process planning into one common activity" (Duffy *et al.*, 1995) in order to overcome the "difficulty of translating needs into production design feasibilities (Calabrese, 1999). Kessler and Chakrabarti (1999), state that DFM is a practice frequently used for project integration and process organization. Essentially, DFM allows for the integration of upstream design with downstream development activities (Kessler and Chakrabarti, 1999; Mabert and Muth, 1992; Millson *et al.*, 1992; Murmann, 1994; Smith and Reinertsen, 1991; Vesey, 1991; Wheelwright and Clark, 1996). DFM relies on information from design (drawings, sketches, and product specifications), manufacturing (estimates of manufacturing costs, production volumes and ramp-up timing) and feedback to the various activity stages (Calabrese, 1999). Along with QFD and CAD/CAM systems, DFM is another of the modeling and analysis tools as categorized by Prasad (1998). "Tools of this level should enable the generation, refinement, quantification and prioritization of requirements... such tools are the result of modeling tools" (Prasad, 1998). The objectives of DFM include reducing design costs and simplifying the production process.

According to Calabrese (1999) and Trygg (1993), this practice has an implicit relationship with NPD cycle time. DFM helps to reduce NPD cycle time through design simplification, part integration and reduction in the number of components (Calabrese, 1999). "As the number of components is reduced and the ease of assembly is improved, there is less design work, less design rework, less product planning, less purchasing, less components, etc." (Trygg, 1993).

Not all research, however, shows support for the frequent use of this practice. While Winner *et al.* (1988) found that the companies studied frequently use design for manufacturing. Portioli-Staudacher *et al.* (2003), on the other hand, found design-for-manufacturing to be one of the least used practices by Italian companies and Belgium companies. Abdalla and Knight (1997) also found that companies were less likely to use this practice in addition to other formal practices or tools.

Failure Mode and Effects Analysis "provides a formal mechanism to resolve the potential problems by (1) identifying all possible ways of component can fail, (2) ranking these ways with a risk priority number, (3) suggesting a corrective action, and (4) calculating the resulting improvement in the risk priority number" (Shina, 1991). FMEA requires that each component be identified along with their corresponding failure modes. Also included in the FMEA are the potential causes and effects of each failure. The RPN is dependent upon the frequency of the occurrence, severity, and the detect ability (Shina, 1991).

Although the literature does not provide evidence for how this practice is related to the reduction of NPD cycle time, it does provide some insight as to the use of this practice. In the research of Portioli-Staudacher (2003) regarding the use of failure modes and effects analysis in Belgian companies, they found that a majority of companies were likely to use it and that it ranked middle of the pack for frequently used practices. The findings for Italian companies, however, much like the findings from this research indicated the opposite and the use of this practice was minimal.

2.6 – How CE practices Reduce NPD Cycle Time

"Concurrent engineering is the use of overlapping activities in products and process development with an objective to reduce Time-to-Market" (Droge et al., 2000).

- The overlapping of activities and/or stages is a powerful tool for reducing product Development Times. The literature confirms the impact of overlap on reducing project completion time. It eliminates bottlenecks and delays by matching design requirements with process capabilities (Calantone and Di Benedetto, 2000).

There are many practices, which make CE possible as identified in Section 2.5. The practices alone, however, do not represent the underlying reasons why products are developed quicker. Product Development Time is reduced when there is a positive relationship between CE practices and certain intermediaries that can affect NPD cycle time reduction known as: the extent of information sharing; timeliness of information; speed of decision-making; explicitness of time goals; goal congruence; linking rewards to goals; and control over development processes (Zirger and Hartley, 1994),. Table 2.7, indicates which CE practices positively impact these intermediaries, thereby increasing the probability of the reduction of NPD cycle time.

Table 2.7 – CE Practices that Reduce the Impact of Intermediaries on Time

Intermediaries	Concurrent Engineering Practices
Extent of Information Sharing	CAD/CAM systems, Co-location, Cross-Functional Teams, Team Leadership
Timeliness of Information	CAD/CAM systems, Cross-Functional Teams
Goal Congruence	Cross-Functional Teams
Linking Rewards to Goals	Rewarding Time-to-Market

In this research it is assumed that information sharing, timeliness of information, goal congruence and appropriately linked rewards to goals are satisfactorily met by the CE practices and do not present a problem for reducing NPD cycle time.

One assumption, however, that is not taken for granted in this research is the gap that could exist between those practices that are frequently used and those that are effective in reducing NPD time. Reasons for this gap include:

1. NPD managers spending time and efforts using practices that do not help improve NPD time performance (i.e., if practices are frequently used but not significantly effective);

2. NPD managers not aligning their actions with their knowledge of the practices that can have an impact on NPD time performance (i.e., if practices are effective but not frequently used); or

3. NPD managers with limited knowledge in using certain practices due the costs associated with them (i.e., if practices are effective but not frequently used). These causes might be further accentuated if there is a high learning curve associated with the use of the different CE practices.

The second and third points above are not mutually exclusive points. There could be a number of reasons why organizations are not putting into use the practices they know to be effective in reducing cycle time. These reasons might pertain to knowledge regarding how to use a particular project or as indicated in point three, the money to properly implement a tool/technique (e.g., computer-aided systems). This gap is investigated in further detail in this research.

2.6.1 – CE Practices Versus NPD Stages to Reduce Cycle Time

This research intends on investigating whether or not the adoption of certain CE practices reduces NPD cycle time. It is probably obvious to point out that NPD cycle time reduction occurs because CE practices are used as the need for their individual contributions arises. CE practices are sometimes even identified as being key for reducing NPD cycle time by applying them to specific stages where their impact is most significant.

In placing CE practices against NPD stages, several researches have examined which practices are associated with particular stages of the NPD process. Karagozoglu and Brown (1993) and Njissen and Lieshout (1995) both looked at new product models and practices in relation to NPD stages. Karagozoglu and Brown (1993) conducted an empirical study to identify the practices that high-technology firms implement during the various stages of the NPD process with the objective of reducing NPD cycle time. They looked at the extent to which the practices[34] were used to reduce cycle time as well as NPD stages or combination of stages[35] for which they were most often used. Njissen and Lieshout (1995) also looked at the extent to which companies used the existing

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[34] The practices they considered included: multi-functional teams, customer involvement, computer-aided tools, benchmarking and progress review, informal-formal organization, style of the R&D budget development, top management involvement, and building on past experience.

[35] The stages they included in their study were: idea generation, technical commercial feasibility testing, resource allocation, project planning, problem solving, product R&D, prototype development, testing, process engineering, and production.

practices[36], their satisfaction with such practices, the relationship between practices and company performance, as well as the stages[37] of the NPD process where the practices would be most useful. Their study was based on qualitative research and data collected through interviews and focus groups of producers of consumer and industrial goods.

This research does in a way identify which CE practices are associated with particular stages of the NPD process as it examines the relationship between CE practices and time variables that are made up of different stages of the NPD process. Time-to-Market is composed of stages: Market Finding, New Product Strategy, Detailed Design and Prototype Development, Pre-Production, and Production. Concept-to-Customer begins with New Product Strategy, and includes Detailed Design and Prototype Development, Pre-Production, and Production. Development Time goes from Detailed Design and Prototype Development to Pre-Production, ending with Production. By comparing the association between the practices and the time variables they reduce, will give some idea as to what stages (within the time variables) are impacted by the practices.

This section ends the discussion of Concurrent Engineering and the reduction of NPD cycle time along with its three time variables. The following sections explain the moderating variable and provide a summary of the literature review (Section 2.7 and 2.8).

2.7 – Innovation

As competition causes rivalry among product success, companies are forced to continuously improve the newness of their products. It can be a good, process or service

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[36] The practices they studied include: brainstorming, morphological analysis, synetics, product life cycle, Delphi method, group discussion, in-home use test, conjoint analysis, quality function deployment, and limited roll-out.

[37] The stages they considered included: idea generation, idea screening, concept development and testing, marketing strategy, business economic analysis, product development, market testing, and commercialization. It should be noted that this study was published in a marketing journal and for this reason might emphasize more the marketing oriented stages.

that they offer customers, and which they want to improve or differentiate significantly from what is already in the market (Zaltman *et al.*, 1973). Companies offer new or significantly improved products as part of their strategic decision to pursue market growth opportunities and compete effectively (Crawford, 1992).

According to the Conference Board of Canada, innovation is "a process through which economic or social value is extracted from knowledge – through the creation, diffusion and transformation of ideas – to produce new or significantly improved products or processes"[38]. Essentially this definition incorporates the activities of the NPD process. The Organization for Economic Cooperation and Development (OECD) Oslo Manual, the internationally recognized standard for innovation measurement, measures innovation using two main categorizations: technological product and process innovations (TPP). Both comprise of "technologically new products and processes and significant technological improvements in products and processes". In order for these products to be innovative, they must have been introduced into the market or used within a production process. They involve a series of innovation-related activities, which make up the NPD process[39]. In its Survey of Innovation, 1999, Statistics Canada, following the Oslo Manual, defines innovation as:

> *"A new product (good or service) is a product which is new to your firm whose characteristics or intended uses differ significantly from those of your firms previously produced products...A new production/manufacturing process is a process which is new to your firm. These involve the introduction of new production/manufacturing methods, procedures, systems, machinery or equipment which differ significantly from your firm's previous production/manufacturing processes..."*[40]

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[38] The Conference Board of Canada (2003) *Trading in the Global Ideas Market*, Ottawa: The Conference Board of Canada.
[39] Organization for Economic Development and Cooperation, *Oslo Manual*, Paris: OECD.
[40] Statistics Canada, *1999 Survey of Innovation*, Ottawa: Statistics Canada.

Key to innovation is its level of uniqueness either in the market or compared to existing products in the firm. The OECD Oslo Manual defines this level of uniqueness or novelty as either "new to the world, new to a nation or new to the firm". While it is not always necessary or possible to create a product that is "new to the world", a product that is "new to the firm" can be construed as not having had any market success in its competitive milieu. Market success is a necessary condition for innovation. A new product satisfies the degree of newness required for innovation but does not necessarily imply market success.

This is perhaps the most significant difference between new product development and innovation. While new product development is the stages of activities that a firm goes through to develop products that are new to the firm, innovation goes one step further to ensure that the product brings value back to the firm.

2.7.1 – 'Type of Innovation' as a Moderating Variable

The following sections seek to explain the moderating variable for this research, define and contrast radical and incremental innovation, and demonstrate the alterations to the NPD process that accommodate their development.

The level of novelty a firm introduces to some extent is dependent on its capabilities and product strategy. Firms determine the extent to which a new product will resemble existing products based on the level of efforts and money they invest into the product development process. If they are focused on speed-to-market, they might be focused on getting more improved products to the market by making incremental changes. Choosing to build upon pre-existing technologies or products can be an effective means of reducing NPD cycle time and getting products out into the market more quickly (Zirger and Hartley, 1994). Gerwin and Barrowman (2001) consider such innovation as an IPD characteristic for NPD cycle time reduction. Incremental changes do not mean that firms never actually develop new products. The changes must make the product significantly improved over other pre-existing products in order to meet the level of uniqueness required for innovation. As delineated by the Oslo Manual, a certain degree of newness is a necessary (albeit not sufficient) condition for innovation. If these changes new satisfy the degree of newness such increments of change to existing product lines can lead to breakthroughs in the market if executed consistently overtime (Clark and Fujimoto, 1991).

If a firm chooses to introduce "incremental innovation", however, as a part of their product strategy, it is arguable whether CE is needed for reducing development cycle time (Smith and Reinertsen, 1998). With incremental innovation less time is spent on generating the idea and designing the new product; efforts are focused on downstream activities (e.g. integrating the changes and adapting manufacturing equipment to support the production of the significantly improved product); and less integration of the stages and the functional departments is needed (Ulrich and Eppinger, 2000). Perhaps CE practices will need to be used less frequently for innovation that involves significant improvements as it does not stress the same activities as radically new products.

On the other hand, it is unknown whether CE efforts to reduce time for radical products may be overshadowed by the need for more idea generating and prototyping activities and less effective in reducing time.

One of the purposes of this study is to examine the use of CE practices for incremental and radical innovation and the extent to which these practices help to reduce

NPD cycle time for each type of product. One of the benefits of this research is that it helps fill a gap in the literature, where 'type of innovation', is rarely considered as a moderating variable with regard to the use of CE practices. Furthermore, many researchers have considered incremental innovation, as a practice on its own for reducing NPD cycle time, rather than a moderator of time reduction. Few researchers have examined the moderating affects of even radical innovation (e.g. Kessler and Chakrabarti, 1999). In addition, the definitions of these two types of innovation are numerous throughout the literature and not always complementary.

2.7.2 – Level of Novelty

According to Dewar and Dutton (1986) innovation varies in the degree of newness or novelty entailed and the measure for which new is defined. A product may be new or significantly improved in comparison to other pre-existing products. Pre-existing products may be in reference to those in the market or existing in the firm. The four dimensions are defined as: new or significantly improved products or processes versus "incremental or radical innovation".

Table 2.8 below provides a brief account of the categorizations possibilities found in the literature. For the purposes of this research, the scope of innovation is around radical and incremental innovation.

Table 2.8 – Review of Literature on Innovation Classifications

AUTHOR	CLASSIFICATION OF INNOVATION
Crawford (1992)	Categorized innovations into three levels: pioneering, adaptation, and imitation. Pioneering innovations relies on creating new products as well as new markets.
Dewar and Dutton (1986)	Categorized as radical and incremental innovations. Radial innovations, or breakthroughs, are "fundamental changes that represent revolutionary changes in technology". Incremental innovations are "minor improvements or adjustments in current technology". They classified the two types of innovations according to the "degree of new knowledge required in the innovation".
Green *et al.* (1985)	Developed a multi-dimensional measure for radical innovations, distinguishable from incremental innovations using four dimensions: technological uncertainty, technical inexperience, business experience, and technology cost.
Henderson and Clark (1990)	Accounted for two further types: modular and architectural innovations. Modular innovations change only the core design concepts of a technology (leave linkages between core concepts and components unchanged) (e.g. analog to digital phone). Architectural innovations leave the core concepts and components the same and change only the relationships between them (e.g. XEROX machine).
Kleinschmidt and Cooper (1991)	In order to determine the relationship between innovativeness and commercial success, they developed three categories of innovativeness for their study: high, moderate, and low. Highly innovative products were those that were "new-to-the-market" products and new to the product lines of the company. Moderately innovation products contribute new lines to the company or new items to existing product lines. They are, however, not considered to be new to the market. Low innovativeness products comprise of all other products that have been modified, redesigned for cost reductions and/or repositioned.
McDermott (1999)	Placed radical and incremental innovations along two dimensions depending on the degree of market uncertainty, and technological uncertainty that characterized them. Radical innovations are high in market uncertainty and high in technological uncertainty. Incremental innovations are low in market and technological uncertainty.
Veryzer (1998)	Distinguished between continuous and discontinuous (commercially, technologically, or both) through two capability dimensions: technological and product. The technological capability refers to "the degree to which the product involves expanding the way product functions are performed beyond existing boundaries" (e.g. products using highly advanced technology but perform the same way). Product capability refers to "the benefits of the product as perceived by the customer or user". Commercially discontinuous products have enhanced product capability and unchanged technological capability. Technologically discontinuous products have unchanged product capability and advanced technological capability (e.g. the change between televisions with vacuum tube and solid stage technology). Combining commercial and technological discontinuity means advanced and enhanced technological and product capability (e.g. Personal computers and pagers).

The following sections describe radical and incremental innovation in more detail and the changes they cause to the NPD process.

2.7.3 – Radical Innovation

Anderson and Tushman (1991) define radical innovation as "technological discontinuities that advance technological state-of-the-art which characterizes an industry by an order of magnitude". Airplanes, automobiles and personal computers were all considered discontinuous or radical innovation when they were first introduced.

Radical innovation is usually characterized as having high relative advantages, minimal similarity with competitors, and high demand uncertainty. Kaluzny *et al.*, (1972) define radical innovation in terms of risk. Radical innovation products typically exist in markets of growth and provide firms with a competitive advantage due to their degree of differentiation against all other products in the market (Gatignon and Xuereb, 1997; and Veryzer, 1998). Also known as breakthrough innovation, it involves creating entirely new products and new markets.

Radical innovation can make significant contributions to the core competencies of firms since it requires building entirely new internal competencies (McDermott, 1999) [41]. It requires a significant degree of new knowledge in technology, which is rarely drawn from the level of familiarity or experience associated with them. It requires a great deal of learning and offer cost and manufacturing advantages only as by-products. It requires champions since internal opposition may arise from manufacturing, purchasing or sales departments, even if the new product is an improvement. It also entails new development and commercialization challenges due to the high level of uncertainty concerning their technological and market feasibility (Crawford, 1992).

Not all ideas for radical innovation are adopted (Dewar and Dutton, 1986). Ideas for radical innovation are often destroyed due to the element of risk and uncertainty they entail. Such innovation is marked by long Development Times which are undesirable

[41] A core competency is defined as the "collective learning in the organization, especially how to coordinate diverse production skills and integrate multiple streams of technologies" (Prahalad and Harnel, 1990). They key attributes of competencies are: they are not easily imitated, and they provide firms access to new markets (McDermott, 1999).

when shortening NPD cycle time is desired. It is also very difficult to support radical innovation. Most internal cultures are not set up to support radical innovation and pressure from within firms often discourage such innovation in the place of efforts directed toward low risk incremental projects (McDermott, 1999).

2.7.4 – Incremental Innovation

With incremental innovation, small changes are made frequently in order to make advancement to the current technology (Dewar and Dutton, 1986). It is often favoured when speeding up the product development process is necessary and can enable firms to be first-to-market. While such innovation does not contribute as significantly to building the core competencies of the firm as does radical innovation, it can lead to lower product costs and improved manufacturability when developing new products (Crawford, 1997). It can also be an important competitive factor for established industries, where major improvements in the manufacturing process can lead to changes in prices or functionality of the product (Nelson and Winter, 1977; Banbury and Mitchell, 1995). NPD managers who fear doing nothing and/or doing anything that could later prove to be worthless also prefer this type of innovation. It allows them to focus on changes they know their customers will appreciate without incurring costs and making risky investment decisions (Veryzer, 1998).

Incremental innovation can be classified into material, operational, scale or product changes. For example, yield improvements to a given production process, modifications in the inputs used in the production process or modifications in the scale and organization of the production process, all refer to process improvements (Malerba, 1992). Product changes entail changing the characteristics of a product in order to reach a new market segment (i.e., horizontal product differentiation); or improving the quality, the physical properties, reliability, performance or integration of the firms products (i.e., vertical product differentiation). Bear in mind, such significant improvements constitute as incremental innovation, if value is extracted from them (Malerba, 1992). For the purposes of this research, incremental innovation refers to product innovation.

Since incremental innovation works best in markets whose products are nearing their mature phase, it is usually used for products such as cars or motorcycles, textiles, software, air grinders, thermostats, mid-size and small computers, toilet fixtures, hand tools and small kitchen appliances (Crawford, 1997).

2.7.5 – Radical versus Incremental Innovation

2.7.5.1 – The Unclear Distinction

As introduced in Section 2.7.1, defining radical and incremental innovation is not trivial. Relative to the existing product lines of the firm, a product might portray significant resemblance and be seen as an incremental innovation. Compared to the market, however, it might entail a degree of newness that its rivals cannot meet. Moreover, incremental innovation can gradually lead to radical innovation, as changes to the product(s) are implemented each time it is introduced.

Clark and Fujimoto (1991) illustrate this through their discussion of Japanese and American automobile projects. They found that Japanese projects commit to smaller amounts of resources and newness, through significant improvements to their products, which American counterparts try to make breakthrough products to disrupt the market. Despite the gap, however, the Japanese products involve pioneering technologies in comparison to those of the Americans.

When defining incremental and radical innovation it becomes essential to specify whether or not the product is defined relative to existing product lines in the firm or to the products in the market. For the purposes of this research, products will be compared to the already existing product lines within the firm. That is, radical innovation refers to a product that is entirely new for the firm and incremental innovation refers to a significantly modified/improved product over previous/existing products of the firm (see Chapter 4 Section 4.1 for the measure of radical and incremental innovation).

2.7.5.2 – Pros and Cons for Radical and Incremental Innovation

There are both pros and cons for both types of innovation. The pros of one are often the cons of the other. Nevertheless, since innovation requires the extraction of value in order to constitute as innovation, both incremental and radical innovation contribute economic benefits to the firm. The decision to adopt either innovation trajectory is dependent on a number of internal and external issues facing the firm (e.g., resource availability, competitive pressures, and strategic objectives).

Looking at the internal issues, the advantages and disadvantages of incremental and radical innovation can be categorized as financial, marketing and engineering related issues. Table 2.9 illustrates the pros and cons of incremental innovation under these headings.

Table 2.9 – Advantages and Disadvantages of Incremental Innovation (Smith and Reinertsen, 1998)

TYPE	ADVANTAGES	DISADVANTAGES
FINANCIAL	Earlier profits Earlier cash flow Less investment risk	Duplicate fixed cost per introduction
MARKETING	Shorter planning horizon Earlier customer feedback More reliable feedback Image of consistent improvement Customer lock-in	Channel overload Sales force overload Customer overload Service and support overload
ENGINEERING	Lower technical complexity More motivating to teams Early field experience with technology Spreads technological commitments	Hard to make technology breakthroughs Boring products
OTHER	Accelerated learning	

The main advantage of developing incremental innovation is to allow firms to consistently bring in modified products without ever exposing the firm to significant amounts of failure due lack of durability or reliability. Project goals such as time, are set shorter for each new project and as they are met, newer goals are introduced for the next project (Clark and Fujimoto, 1991). Smith and Reinertsen (1998) found that "the easiest way to shorten development cycles is to minimize the work required to develop the product [through incremental innovation]".

Unlike incremental innovation, radical innovation projects are often destroyed due to the element of risk and uncertainty they entail. The exposure to higher probabilities of failures (e.g., durability or reliability of the product) is usually the greatest challenge when dealing with ideas for radical innovation (Clark and Fujimoto, 1991). Uncompleted projects lead to a break in the momentum for improvement and continuous success the firm tries to maintain for developing better products. Radical innovation projects are also are more difficult to complete quickly and require a large degree of training and development of staff (Crawford, 1992).

Despite the internal issues, however, the environment is also a critical element when deciding what type of innovation to undertake. The pressures from the external environment sometimes dictate what is required of the firm in order sustain business performance or even just survive. Despite the advantages of incremental innovation, such innovation can be an obstacle for profitable breakthrough types which might be required for survival. Incremental innovation sometimes threatens the opportunity for a firm to introduce breakthrough or pioneering technologies to the market. Radical innovation might be the answer for penetrating a market or creating a new one (Crawford, 1992).

2.7.6 – NPD: Radical vs. Incremental Innovation

The NPD process differs for radical and incremental innovation. Ideas for radical innovation progress through the NPD process differently than ideas for incremental innovation (Kessler and Chakrabarti, 1999; Veryzer, 1999). Conventionally, emphasis on the NPD process is placed on the front-end activities (i.e. defining the market opportunities and finding a product that suits customer desires). In the case of radical innovation it is difficult to define the market and gain knowledge from it, because introducing a really new product means creating the demand for it. Customers usually consider these products as meeting needs and desires they hadn't realized they had.

As discussed earlier, there are many ways of describing the NPD process. According to Song and Montoya-Weiss (1998), the NPD process includes: strategic planning, idea development and screening, business and market opportunity analysis, technical development, product testing, and product commercialization. While thir model is not the best one for NPD, excluding important stages (e.g. manufacturing start-up and prototype development) it is useful for explaining the key differences in the determinants of NPD success between radical and incremental products. Table 2.10 ranks the steps of the NPD process as defined by Song and Montoya-Weiss (1998) by importance for each type of innovation. Evidently, strategic planning and business and market analysis are two areas where radical and incremental innovation differ.

Table 2.10 – Ranking NPD activities by Type of Innovation (Song and Montoya-Weiss, 1998)

RANKING	RADICAL	INCREMENTAL
1	Technical Development	Technical Development
2	**Business and Market Analysis**	**Strategic Planning**
3	Commercialization	Commercialization
4	Idea Development and Screening	Idea Development and Screening
5	**Strategic Planning**	**Business and Market Analysis**
6	Product Testing	Product Testing

For the incremental NPD process, spending time on post-development stages (such as business and market opportunity) is critical for capitalizing on prior knowledge. For radical innovation, focusing on technical development activities and product testing are critical to delivering a new product (Song and Montoya-Weiss, 1998).

Radical innovation is less certain, and involves a great deal of experimentation, learning, and problem-solving (Kessler and Chakrabarti, 1999). "Factors such as uncertainty of suitable applications for the technology and the greater distance from the market in terms of time and customer familiarity with the product affect the nature of the development process [for radical innovation]" (Veryzer, 1998). Activities such as design and prototyping need to come very early on in the process, much before market assessment and other front-end activities. According to Ulrich and Eppinger (2000), unlike with incremental innovation where product architecture is included at the same time as product concept, for radical innovation it is not known until the design stages.

Due to the nature of radical innovation, the NPD process needs to be more informal for such innovation to take place. In fact, stage-gate models have not proven to necessarily support radical innovation. This research searches for ways of supporting such innovation through CE practices.

2.8 – Summary of Literature Search

In the previous sections of this literature review, the New Product Development Process, the Integrated Product Development Process, and Concurrent Engineering were all described. The CE practices that are expected to reduce NPD cycle time were defined along with a way of measuring NPD cycle time, in terms of Time-to-Market, Concept-to-Customer, and Development Time. This metric for time was adopted from the work of Griffin (1993).

The CE practices adopted for this research come from the research of Barclay and Dann (2000) where they designed a model of the NPD environment including the commonly used practices. These practices are a compilation of practices frequently referenced in the literature by other researchers studying the impact of practices on NPD cycle time.

A moderating variable, type of innovation, was also explored. Innovation may be either incremental or radical, where incremental innovation involves building upon pre-existing technologies or capabilities to introduce significantly improved products into the market and radical innovation involves developing firm-first capabilities that involve a great deal of uncertainty and risk resulting in completely new products introduced into the market. According to Griffin (1997) there is a lack of data or study on the affects of innovation newness on NPD cycle time, making type of innovation an important and unique moderating variable to examine.

Certain studies were identified where the notion of newness as a moderating variable was explored. Griffin investigated the relationship between certain factors and NPD cycle time and how the relationship is moderated by product newness and product complexity. In this same study she made hypotheses about the effects that product newness and product complexity both have on NPD cycle time.

Emmanuelides (1993) included project scope as a contextual factor in his "integrative framework of performance in product development projects", which encompassed product newness and product complexity. He postulated that product newness and technological complexity would both be associated with longer cycle time. Since then, Kessler and Chakrabarti (1999) have looked at the moderating effect of "radicalness" on factors leading to NPD cycle time reduction.

Studies by Clark and Fujimoto (1991) and Gerwin and Barrowman (2001) provide insights as to the implications of including 'type of innovation' as a moderating variable. Looking at incremental innovation as a part of product strategy (Clark and Fujimoto, 1991) and a characteristic of IPD for reducing NPD cycle time (Gerwin and Barrowman, 2001), these two studies contribute two important areas for clarification. First before discussing type of innovation it is essential to clarify whether incremental or radical innovation is relative to the existing product lines of a firm or to products in the market. Second, when looking at incremental innovation as a moderating variable it is important to note that such innovation is like CE practices in that it is one of the IPD characteristic used to reduce NPD cycle time.

Based on the review of the literature, the research model is introduced in Figure 2.9 of Chapter 3, Section 3.4. It outlines the relationship between CE practices and NPD cycle time; measured in terms of Time-to-Market, Concept-to-Customer, and Development Time; with 'type of innovation' moderating the relationship.

Chapter 3 – Theoretical Framework

3.1 – Research Problem

To what extent do Concurrent Engineering (CE) practices reduce New Product Development (NPD) cycle time measured in terms of Time-to-Market, Concept-to-Customer, and Development Time in Canadian Electronic Manufacturing organizations?

3.2 – Research Objectives

There are a number of researchers who have looked at different CE practices, many of which are included in this study, and the impact these practices have on NPD performance, such as the reduction of cycle time. These researchers have all been referenced in Appendix VII and it is not the purpose of this research to repeat their work. Very little research work has yet examined the four major groups of practices as listed by Poolton and Barclay (1998) and their affects on NPD cycle time measured in terms of three time variables; Time-to-Market, Concept-to-Customer, and Development Time, as identified in Section 2.3.1.

In order to study the relationship between CE Practices and NPD cycle time, the objectives of the research are twofold. The **first objective** of this research is to *examine the extent of use of CE practices in Electronic Parts and Components firms.* The **second objective** is to *identify what are the critical CE practices for reducing NPD cycle time, measured in terms of Time-to-Market (including Market Finding, New Product Strategy, Detailed Design and Prototype Development, Pre-Production and Production), Concept-to-Customer (from New Product Strategy until Production), and Development Time (from Detailed Design and Prototype Development until Production).*

3.3 – Research Questions

Combining the two objectives described above along with the research question, the following investigative questions examined include:

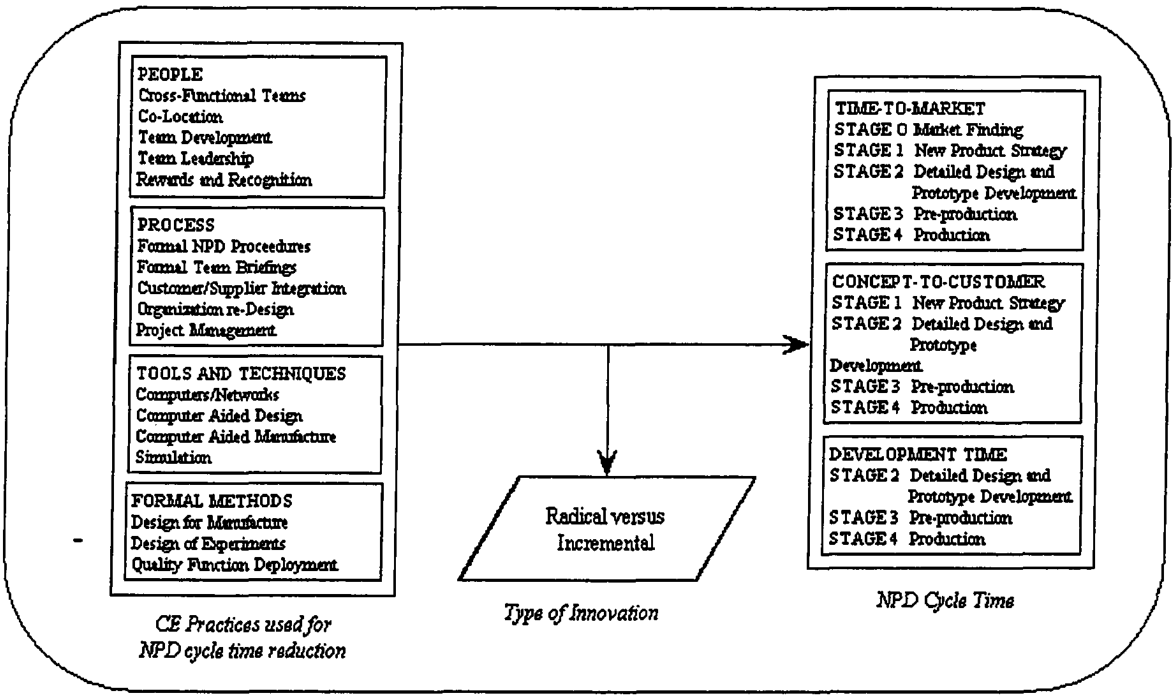
1. What CE practices are frequently used in New Product Development projects of Canadian Electronic Parts and Components organizations? How does use differ by type of innovation?
2. To what extent are these practices effective in reducing NPD Cycle Time, measured in terms of Time-to-Market, Concept-to-Customer, and Development Time? How does effectiveness differ by type of innovation?
3. What gap exists, if any, between the actual usage of the CE practices and the perceived usefulness of the CE tools as seen by the NPD managers for reducing NPD cycle time? How does the gap differ by type of innovation?

3.4 – Research Hypotheses

Based on Tables 2.3 (NPD Stages) and 2.6 (CE Practices), and Figure 2.5 (Time Metrics of NPD Process) the proposed research model in Figure 2.9 was formulated. According to the literature, CE practices have an impact on the performance of NPD, specifically on the time dimension of such performance. The model indicates that the relationship between CE practices and NPD cycle time can be broken down when NPD cycle time is measured in terms of Time-to-Market, Concept-to-Customer and Development Time. Certain practices might be more useful for reducing the three different time measures than others.

The type of innovation trajectory chosen moderates this relationship. The two types of innovation considered in the scope of this research, radical and incremental innovation, impact CE because of the elements that are associated with them (e.g. level of complexity, degree of uncertainty, amount of knowledge on hand, the level of newness). Radical and incremental innovation was explained in Section 2.7. Of course there can be other moderators for this relationship, such as environmental, organizational and product project factors. These factors are not considered in this study and are included in Section 6.2 on limitations.

Figure 2.9 – Conceptual Model



3.4.1 – Hypotheses

The following hypotheses to be tested are discussed in the following section. They address the relationship between CE practices and NPD cycle time separately and the extent to which this relationship is affected depending on type of innovation. While some CE practices help reduce CE practices others do not. The purpose of this study is to eventually identify those that do and those that detract from NPD time reduction. It is important for those firms competing in fast-paced markets to avoid those practices that reduce their competitive capabilities.

The hypotheses discussed in the following section relate to the second objective; to determine the critical CE practices that are effective in reducing NPD cycle time, in terms of the three time measures; Time-to-Market, Concept-to-Customer, and Development Time; as they allow for the practices to be tested for the relationship.

3.4.1.1 – People Practices

If a firm is using CE than functional divisions should be interacting with one another at the beginning of the project. Such interaction is not always simple. People practices support the collaboration that takes place between the different functional units. These practices allow for more frequent communication and transcendence of information across boundaries. Two practices in particular, cross-functional teams and co-location, help improve communication. Team rewards, leadership, and development, are also important for supporting collaborative initiatives. They provide direction and clarify as to what behaviours the organization values and rewards. These values are usually strongly linked to the performance of the organization.

At the same time a practice like co-location can have a negative impact on NPD cycle time. As Kahn and McDonough (1997) point out in their study, although co-location is significant for increasing collaboration, it does not have any significant relationship with performance. It can also be associated with high costs for facility management and take time to implement.

As for cross-functional teams (CFT), Karagozoglu and Brown (1993) point out that cross-functional teams notably increase the amount of tension and conflict among workers, reduce management's control, and require members with sufficient team skills. Finding technical people who also work well with others is not always an easy task. Of the high-technology firms studied, cross-functional teams were only used at certain stages of the NPD process; mostly during the downstream phases where problems were more easily avoidable.

On the other hand, other researchers found support for the use of cross-functional teams for pre-development stages in order to reduce time and conflict later on (Cordero, 1991). Zirger and Hartley (1994) also support this finding; they state that cross-functional teams reduce the time needed for information processing when they are formed from the beginning of a project, the point at which product definition, functional issues and constraints, and project goals are formulated.

The confusion as to what point of the NPD process to use cross-functional teams suggests that cross-functional teams can contribute to the reduction of NPD cycle time, by reducing a particular time measure; Time-to-Market, Concept-to-Customer Time, or Development Time, so long as it used at the right stage. By identifying which measure of time is reduced by cross-functional teams, the results will also indicate what stage is most appropriate for the implementation of this practice.

HYPOTHESIS 1

a) *Adoption of people practices reduces the Time-to-Market of new products.*

b) *Adoption of people practices reduces the Concept-to-Customer Time for new products.*

c) *Adoption of people practices reduces the Development Time for new products.*

3.4.1.2 – Process Practices

There are "some practices that improve the flow of product and process information during development". Process practices are amongst those practices that provide the means for sharing information, which may later be translated into action. The information they provide is essential for establishing the framework for direction setting in the NPD environment and achieving CE goals. Without this information, CE can dramatically hinder the performance of a new product developing organization (Lynn *et al.*, 1999) by causing delays in development (Pawar and Sharifi, 1997). With respect to reducing cycle time, process practices are crucial for feeding the necessary information inputs into other CE practices quickly and helping to increase concurrency of activities through management of the information flow (Gupta and Wilemon, 1990; Liker *et al.*, 1995).

Process practices such as formal team briefings and project management reduce the time needed for information sharing and decision-making, explicitly stating goals, and linking rewards to the fulfillment of goals – all of which are ingredients for cycle time reduction (Zirger and Hartley, 1994).

Akin to people practices, there is also research that opposes the use of process practices for reducing NPD cycle time, in terms of Time-to-Market, Concept-to-Customer Time, and Development Time. The main issue is that process practices can sometimes make the NPD process too rigid. The very core competencies of the formal process can manifest itself as core rigidities (Leonard-Barton, 1992). Examples of where process practices can become too rigid includes: overly formal team briefings, inflexible project management styles, overly late or early involvement of customers/suppliers, restrictive formal NPD procedures or drastic organizational re-design that makes it too difficult for staff to adapt to the changes.

HYPOTHESIS 2

a) *Adoption of process practices reduces the Time-to-Market of new products.*
b) *Adoption of process practices reduces the Concept-to-Customer Time for new products.*
c) *Adoption of process practices reduces the Development Time for new Products.*

3.4.1.3 – Tools and Techniques

Tools and techniques refer to computer-based tools such as CAD and CAM. These tools "can dramatically reduce product design time as well as the number of prototypes that must be built" (Karagozoglu and Brown, 1993). In a Liker *et al.* (1999) study, CAD/CAM systems were strongly related to a reduction in the time it took for tooling. These systems can also have a large impact on engineering performance when used as a communication medium (Robertson and Allen, 1993).

Although, literature supports the association between this group of practices and time reduction, Moffat (1998) cites a number of different studies where CAD/CAM tools were not associated with product development performance measures, such as time. Karagozoglu and Brown (1993) state that "despite the benefits associated with the use of computer-aided tools to speed up activities in several of the NPD phases, nearly three-quarters (73.6%) of the firms...used computer-aided tools only in a single phase"[42]. According to Hauser and Clausing (1988) use of such tools in the downstream stages can be due to the inexperience of using them at the earlier stages.

If tools and techniques are likely to be used more prominently in one stage than another, it suggests that certain tools and techniques will be better at reducing the

[42] The majority of the firms used these tools for the planning and resource allocation stage (33.3%) (a stage not uniquely identified in this research) and in the prototype development and testing phase (20%).

measure of cycle time that corresponds to the stage(s) in which the tool or technique is being used. For example, if these practices are more likely to be used in downstream stages, it is possible that they will have a stronger relationship with Development Time (a measure of time that encompasses the downstream stages).

Gupta and Wilemon (1990) also note that the use of tools and techniques might be "inappropriate for NPD due to the uncertainties usually inherent in the innovation process". Tools and techniques also carry with them a major obstacle for NPD time reduction in their implementation and capital costs.

HYPOTHESIS 3

a) *Adoption of tools and techniques reduce the Time-to-Market of new products.*
b) *Adoption of tools and techniques reduce the Concept-to-Customer Time for new products.*
c) *Adoption of tools and techniques reduce the Development Time for new products.*

3.4.1.4 – Formal Methods

This group of practices is usually categorized as "analytical methods [that] optimize a product's design and its manufacturing and support processes" (Trygg, 1993). They are used at different stages of the development process to serve a variety of different purposes, including the reduction of NPD cycle time through concurrency of activities (Hauser and Clausing, 1988).

Given the fact that the majority of these practices are design-oriented and used in the detailed design and prototype development stage they are expected to be most effective in reducing the time it takes to transform the idea into the actual product.

Some of these practices might prove to have no association with the reduction of NPD cycle time. According to Njissen and Lieshout (1995), QFD, a practice extensively used during the idea generation, idea screening, concept development and testing, and product development stages[43], had no relationship with cycle time reduction in a study by Trygg (1993).

HYPOTHESIS 4

a) *Adoption of formal methods reduces the Time-to-Market of new products.*
b) *Adoption of formal methods reduces the Concept-to-Customer Time for new products.*
c) *Adoption of formal methods reduces the Development Time for new products.*

3.4.1.5 – Moderated Relationship

Referring back to the discussion in Section 2.7.5, Song and Montoya-Weiss (1998) pointed out that their study found a difference in the importance placed on certain activities within the NPD process depending on the type of innovation. Type of innovation refers to incremental and radical innovation, for the purpose of this study. The implication their finding is that certain practices might also be more important at different stages of the NPD process for radical versus incremental innovation. Since incremental innovation builds upon pre-existing knowledge, there might be a lesser need for highly integrated manufacturing and design activities. Moffat (1998) found that Design for Manufacture and information system tools were more supportive of incremental innovation.

Liker *et al.* (1999) was found that the more novel the innovation the greater the flexibility needed. Practices such as cross-functional teams, co-location, team rewards and customer/supplier involvement were among those practices that were more supportive of the design/manufacturing integration required for radical innovation.

The work of Kessler and Chakrabarti (1999) also provides evidence to support the above hypothesis that certain practices work better than others for radical versus incremental innovation. They found that CAD systems increase cycle time for radical

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[43] Over 50% of the firms studied used QFD for these stages.

innovation due to over preoccupation with computers, inappropriate implementation of the CAD system or inappropriate use. Regarding team autonomy, they found that this practice reduced cycle time only for radical innovation due to the lack of clarity of tasks and missing methods for fulfilling activities. Empowerment was more effective for radical innovation since uncertainty and complexity of the innovation was higher. Co-location was also found to be more useful for reducing the NPD cycle time of radical innovation, as it was suggested that less communication is better for incremental innovation in order to prevent "unnecessary complexity and more frequent interruption of tasks". Co-location also allows for better decoding and synthesizing of information due to high uncertainty related to radical innovation. Design for manufacture also had differing results for radical and incremental innovation (Kessler and Chakrabarti, 1998).

Despite the findings of Kessler and Chakrabarti (1998) they are referenced with caution. Their study has a very small size and thus provides less reliability. While this study also a low sample size, complements between each study can be used to strengthen the findings.

HYPOTHESIS 5

a) *People practices, process practices, tools and techniques, and formal methods will all have different effects on reducing Time-to-Market for incremental and radical innovation.*

b) *People practices, process practices, tools and techniques, and formal methods will all have different effects on reducing Concept-to-Customer Time for incremental and radical innovation.*

c) *People practices, process practices, tools and techniques, and formal methods will all have different effects on reducing Development Time for incremental and radical innovations.*

Chapter 4 – Research Methodology

This research is intended to be a cross-sectional study of Canadian Electronic Parts and Components firms. The empirical data that has been collected focuses on determining which CE practices are most effective for reducing NPD cycle time and more specifically which practices can be emphasized to reduce Time-to-Market, Concept-to-Customer Time, and Development Time (all defined in Section 2.3.1). The data collected is based upon the perceptions of NPD managers (includes R&D managers, project team leaders, etc.). The survey data provides insight for NPD managers of Canadian Electronic Parts and Components firms utilizing CE and other similar type firms employing CE where their primary activity is manufacturing/processing/producing products. The data also provides researchers with insights regarding the use of practices for the reduction of NPD cycle time.

4.1 – Survey Instrument and Measures

The research objectives identified in section 3.2 are fulfilled by means of a survey instrument: a mailed or faxed questionnaire accompanied by telephone interviews in order to attain a higher response rate (see Appendix XIV). Table 4.1 outlines the questions used in the survey and their objective.

Table 4.1 – Survey Questions and Objectives

OBJECTIVE	QUESTION
Verify the use of Concurrent Engineering	1) To what extent, on a scale from 1 to 7, do interactions take place among different departments (such as Design, Manufacturing and Marketing) during the process of product development, where 1 is "no interactions at all" and 7 is "extreme interactions". 2) Please indicate whether or not phases of the New Product Development process were overlapped for the project.
Identify the level of importance that NPD managers place on CE practices for reducing NPD cycle time	In your opinion, how important are the following Concurrent Engineering (CE) Practices for reducing the time needed for the overall development of a new product, on a scale from 1 to 5.
Identify the level of newness of the product	Please think of a product introduced within the last six months to a year that was successfully marketed by your firm. Was this product: a) entirely new to your firm, b) significantly modified/improved over a previous/existing product of your firm, or c) a minor modification to a previous/existing product of your firm.
Determine the extent to which NPD managers use CE practices	To what extent, on a scale from 1 to 5, were the following Concurrent Engineering (CE) Practices were used in the overall development of the product?
Identify the extent to which NPD cycle time is reduced, measured in terms of Time-to-Market, Concept-to-Customer and Development Time	Please estimate the amount of Time-to-Market reduction that was achieved as a result of the use of CE practices for the development of the product you have been thinking of. Same question for Concept-to-Customer Time and Development Time.
Determine the extent to which NPD managers perceive CE practices to have actually reduced the Time-to-Market of their product	To what extent, did the following practices actually reduce Time-to-Market needed for the development of the product?

Use of Concurrent Engineering

Two questions are used to determine whether or not the project falls within the target sample. Only those projects that employ CE will be included. This is done using a measure that meets the requirements of the definition of CE as identified in the literature review. Firms were contacted by telephone to answer these two questions before completing the survey for pre-screening purposes.

Ainscough and Yazdani (2000) believe a firm is using CE if there exists: a formal new product introduction process, cross-functional team work, CE tools and techniques, process enabling information technologies, and project management activities. All of these are included in the groups of practices included in this study (identified in Section

2.5). In order to ensure that CE was in use in developing the product, NPD managers were asked to indicate:

- Whether or not phases of the New Product Development process were overlapped for the project; and
- To what extent, on a scale from 1 to 7, do interactions take place amongst different departments (such as Design, Manufacturing and Marketing) during the process of product development, where 1 is no interactions at all and 7 is extreme interactions.

A firm is said to be using concurrent engineering if the respondent answered affirmatively to the first question and if they responded four or higher on the scale of 1 to 7 for extent to which the different departments interacted with one another.

Importance Placed on CE Practices

The question on importance placed on CE practices was meant to assess the level of importance that NPD managers place on the CE practices when it comes to reducing NPD cycle time.

Level of Newness of the Product

A question on level of newness of the product was introduced into the survey for the purposes of investigating differences in the relationships between the practices and NPD cycle time (in terms of the three time measures) for two types of innovation, radical and incremental.

The literature indicates a number of different ways for categorizing type of innovation. According to Kessler and Chakrabarti (1999) radical innovation can be operationalized using two scales. These scales measure the type of work done on the project and the degree of change involved in the project. Barclay and Dann (2000) define product newness as the newness of: the concept, the design, the manufacture, the marketing of the product *for the company*, as well as the newness of: the concept, the benefits, the appearance and the application of the product *for the customers*.

This research focuses on the perceptions of the respondents in classifying the product of the NPD project as either new or significantly improved. New or significantly improved products typically mean new to the firm. Other terms, such as incremental and radical innovation usually have a market specific element in their definition. While radical innovation is usually totally new to the firm they can also be significant improvements over products already existing in the firm. Intuitively, this would mean that a firm is far ahead of the market and is continuously causing disruptions to the market just improving its radical product.

It is difficult to measure the level of newness of a product to those in the market. The 1999 Statistics Canada Survey of Innovation asks respondents to indicate whether they consider their new or significantly improved product to be firm-first, Canada-first or world-first. While radical innovation products would most likely be the world-first products, Statistics Canada's reports continue to refer to such products as new. Other researchers that have admittedly studied incremental versus radical innovation have used definitions of new or significantly improved products in order to distinguish between the two types of innovation. This research follows their path, however, recognizes that the only way to truly understand if a product is radical is by measuring the amount of disruption it has caused in the market. This research, however, does go one step further than those of other researchers.

In the survey, respondents were asked to think of a product introduced within the last 6 months to a year that was successfully marketed by the firm and to identify whether this product was:

- Entirely new to the firm;
- Significantly modified/improved over the previous/existing product; or
- A minor modification to a previous/existing product

If the respondent checked off the first option the product was considered or categorized as a radical innovation. Incremental innovation is indicated by the second option. The final option was used to screen out those products that were not new or significantly improved and not part of innovation.

This measure is a variation of that used in a study by Liker *et al.* (1999), where design newness measured minor modifications to existing designs, major modifications of existing designs, and new designs[44]. The difference is that this research makes considers minor modifications more like continuous improvements, not truly meeting the newness requirement for a product to be part of innovation.

Extent of Use of CE Practices

The idea for this question came from the research of Njissen and Lieshout (1995) and Karagozoglu and Brown (1993), which looked at the extent to which practices were used. It examines the extent to which NPD managers use CE practices in the overall development of their products. In order to understand the gap between those practices that are perceived to be important for reducing cycle time and those that are actually used, respondents were asked to what extent they actually use the list of CE practices.

[44] Liker *et al.* (1999) do state that this measure can "overstate design newness because it is based on established product platform rather than fundamentally new product".

Extent of NPD Cycle Time Reduction

The intent is to determine by what percentage NPD cycle time, measured in terms of Time-to-Market, Concept-to-Customer, and Development Time, is reduced as a result of using CE practices. This measure gives a general sense of the contribution CE practices make in reducing NPD cycle times. When considered in combination with Measure 4, this question serves to address the gap between the frequencies of use of CE practices for a particular project and the extent to which time was reduced. This measure also serves to verify the consistency of the responses by linking it to the practices that NPD managers actually use.

The question used for this measure is similar to that used in McDonough and Barczak (1991) and McDonough III (1993) on reducing the time needed for NPD projects. It is also in accordance with Rusinko's (1997) study where time was defined as a scale that measured the "degree in a meeting project time goal, weighted by goal importance".

Reduction of Time-to-Market by CE Practices

Part VI measures the actual performance of CE practices in reducing Time-to-Market based on the perceptions of NPD managers. The question asks managers about their perception as to the extent to which an individual practice contributed to reducing NPD cycle time. In some way it is linked to the question of usage, as a practice that is seen to largely reduce cycle time would intuitively also be a practice used by managers.

4.2 – Sample

4.2.1 – Survey Population

Defining the population was one of the most critical components of this research. According to Gerwin and Moffat (1997) there is an "obvious difficulty in defining a population of firms utilizing CE".

In order to ensure that only companies using CE were selected for the study a number of different studies were relied upon to properly define the population. According to Duffy and Salvendy (1998) and Duffy *et al.,* (1997) manufacturing firms using AMT are most likely to be using CE for NPD. Firms using Advanced Manufacturing Technology (AMT)[45] or Discrete Manufacturing[46] were identified from the list of firms included in the specialized directory for Information and Communication Technology firms on Industry Canada's Strategis Website (www.strategis.gc.ca) [47].

Industry Canada's Strategis (www.strategis.gc.ca). The major users of AMT applications include manufacturers of automotive, electronics, aerospace, and electrical industries. Of these sectors, Ainscough and Yazdani (2000) found that electrical manufacturers were the most likely to be using CE. In order to ensure a large enough population to draw from, companies from industries such as Aircraft and Parts, Electronic or Electrical Industrial Equipment, or Telecommunication Equipment were considered for this study.

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[45] AMT involves new manufacturing techniques and machines combined with information technology, microelectronics, and new organizational practices in manufacturing processes. It is key for meeting productivity, quality, and cost reduction demands of competitive global markets (www.strategis.gc.ca).
[46] With Discrete Manufacturing, operations are integrated in order to reduce the time needed for manufacturing. Design is linked to manufacturing through computers, and marketing, sales, design, production and delivery are part of an enterprise-wide manufacturing system (www.strategis.gc.ca).
[47] The Electronic Parts and Components Industry include the following products: connectors, miscellaneous, power supplies, printed circuit boards, semiconductors, and microelectronics. Also included is electronic manufacturing services, however, no firms were selected from this last group.

An attempt to define the survey population by size (number of employees) of the organization was made. As suggested by Lynn *et al.* (1999) medium and large size firms "[are] more likely than small organizations to adopt CE practices, and their economies of scale may help them achieve greater cost-savings from concurrent engineering efforts". Large firms are also more likely to have established NPD programs (Kessler and Chakrabarti, 1999).

According to Statistics Canada and Industry Canada, medium firms are those that employ between 100 to 499 employees, and large firms employee 500 or more. Despite these definitions and the support to include only medium to large firms in the sample, limitations in collecting survey made it necessary to include some smaller firms. These firms (less than 100 employs), however, did meet the screening requirements as being firms using CE.

If a company out-sources its manufacturing activities, such companies were still included in the target population so long as they do their own design work and interact with the manufacturing. The problem occurs if the company "throws their design over the wall" to the outside contractor and is not involved with the overlapping of the design and manufacturing stages. This is one of the reasons for measuring the extent to which the company overlaps its design and manufacturing activities. It specifies whether or not the company is involved in design activities. If a company did not take part in any design activities, they were excluded from the population. Thirty companies were excluded due to this reason. It was assumed that they would not be very knowledgeable when commenting on the practices, especially since they are most design-oriented practices.

Such companies were identifiable with the information provided in the company descriptions included on Industry Canada's Strategis web-site[48].

4.2.2 – Sample Frame and Sample Size

The sample selected is at the organizational and project level. At the organizational level the sample consists of medium or large sized companies that overlap their activities and rely heavily upon the interaction of different functions, that were willing to participate, and that fall within the following industries: Electronic Parts and Components, Aircraft and Parts, Electronic and Electrical Industrial Equipment, and Telecommunications. Again, these industries were included in this study due to the success previous researches have had in identifying companies using CE (Duffy and Salvendy, 1998; Duffy *et al.*, 1995; and Gerwin and Moffat, 1997). For a list and table describing the companies considered for this study, see Appendix XV. The sample size consists of 20 projects from 15 companies, whereby 14 projects qualified as incremental innovation projects and 6 qualified as radical innovation projects.

All questionnaires completed and returned must meet the following criteria to be included in the sample:

1. The firm must have introduced a new or significantly improved product in the last 6 months; and
2. The product must have (be) proven (proving) to be successful in the market.

This requirement eliminates companies that might have developed products using CE that did not succeed in the market. Success refers to some economic value extracted as a result of customers having used or bought the new product.

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[48] Based on discussion with Dr. Linda M. Moffat, Professor at Carleton University.

The typical respondent chosen as the individual level are NPD managers in charge of a new product using CE and aware of the different practices involved with CE. This is important to ensure that the respondents are able to share knowledgeable insights regarding the CE practices.

Due to the difficulties in attaining responses, the *sample size* consists of more than one NPD project from the set of firms. Each responding firm was requested to fill a separate questionnaire for at least 2 to 4 NPD projects where CE was being used to develop the new or significantly improved product. In total, surveys for 20 projects were collected from 15 firms. Fourteen of these projects satisfied the condition for incremental innovation projects and six satisfied the condition for radical innovation projects.

4.2.3 – Unit of Analysis

The unit of analysis for this study is at the project level. As seen in Appendix VII the majority of empirical studies regarding NPD projects are done at the project level. The results are not generalizable on firms or their industries but indicate the tendency of NPD project managers to use certain practices more frequently and perceive certain practices as more effective in reducing NPD cycle time; measured in terms of Time-to-Market, Concept-to-Customer, and Development.

4.3 – Reliability and Validity Issues

There are a few validity and reliability issues to be addressed for this research. The discussion begins with the degree of confidence related to this study, or the internal validity of the study. There are three aspects that are applicable here:

- *History:* The number of high-technology firms in the Electronics Industry that have failed or forced to dramatically downsize their workforce (e.g. Nortel) might have an affect on biasing the perceptions of NPD managers regarding practices that were being used, such as CE Practices.

- *Selection:* The testing process might also affect the responses of participants. Because the participants are to be individually selected by upper management it is unknown if all NPD managers would answer similarly. Participants might feel compelled to answer favourably regarding questions related to the performance of the project. They might feel as if being watched by upper management.

- *Bias:* A manager with a relatively less successful project may blame the CE practices. It would have been preferable to have different respondents scoring the practices and other scoring the reduction in time.

One validity issue has to do with the measurement scales used. Since the majority of the questions have been taken out or adapted from previous studies, it is reasonable to assume that they are indeed measuring what they are supposed to. The questions that are new to the study include the question regarding the actual use of concurrent engineering and the question regarding percentage of time reduced for the three NPD cycle time measures. It is possible that these measures are subject to problems with content validity. Although the literature has been exhaustively searched, the items included in the measures are also somewhat subjective to what the researcher finds important to include.

Another validity issue, construct validity, is somewhat dealt with as the issue of convergent validity is addressed. By pre-testing the questionnaire with two experienced respondents helped to address the issue of content validity.

Chapter 5 – Data Collection

5.1 – Data Collection

As previously mentioned, Gerwin and Moffat (1997) pointed out the difficulties of collecting data from firms engaged in Concurrent Engineering. In this research firms were selected based on their propensity to use CE which was confirmed in a pre-screening telephone call. The most senior person from R&D or Development (e.g., NPD manager or Vice President) was the targeted contact person. He/She was asked to answer a couple of questions related to the definition of CE as used in this research. If the answers provided adequately suggested that the project involved CE the firm was asked to take part in the study. The typical respondent was the project team leader or R&D manager responsible for an NPD project using CE practices.

Once the actual respondent was identified, a pre-notice letter was mailed to him/her by mail or fax along with a consent form explaining their rights as a participant (see Appendices XV and XVI). On the consent form respondents were asked to specify whether they wanted a copy of the results and to where the results should be sent.

The self-administered questionnaire was mailed a couple of days after the pre-notice letter and consent form, and respondents were given two and half weeks to complete. Accompanied to the questionnaire was a cover letter indicating the objectives of the research and the importance of the respondent's contribution (see Appendix XVIII). All questionnaires and consent forms sent to respondents were accompanied with a self-addressed stamped envelope. A thank you postcard was also sent, in part to remind the respondent of the questionnaire (Appendix XIX).

Chapter 6 – Data Analysis

In accordance with the research questions described in Section 3.3, this data analysis examines the perceived importance of CE practices, the frequency of use of these practices, the relationship between CE practices and performance, and the relationship between the actual usage of the practices and their perceived usefulness in reducing NPD cycle time.

6.1 – Overview of Responding Organizations

The sample consisted of 20 projects from 15 manufacturing companies from the Electronics Parts and Components sector whose primary business activity is manufacturing, processing and producing. The types of products fall under the following manufacturing sub-groups:

- Computer and electronic product manufacturing
  - Semi-conductor and other electronic component manufacturing (e.g., semi-conductors)
  - Communications equipment manufacturing (e.g., digital communication recorders)
  - Navigational, Measuring, Medical and Control Instruments Manufacturing
- Electrical equipment, appliance and component manufacturing
  - Electrical equipment manufacturing (e.g., transformers)
  - Household appliance manufacturing products (e.g., passive microwave components & sub-systems for wireless/satellite communications)
  - Electrical Equipment Manufacturing
  - Other Electrical Equipment and Component Manufacturing

Two variables were used to screen out respondents that did not meet the requirements for CE. One of them, the interaction variable from the survey (Appendix XIV, question 3), asked respondents to identify on a scale from 1 (no interactions at all) to 7 (extremely high interactions) the degree to which departments (such as design, manufacturing, and marketing) interacted with one another during the development o new products. A response of four (the mid-point of the scale) or over was satisfactory for the first level of screening. For those organizations that passed the screening, the average level of interaction of functional areas is 5.7 on a 7-point scale.

The second variable used to screen respondents was based on whether or not stages of the NPD process were overlapped. Respondents were asked to answer "yes" or "no". A negative response excluded the respondent from the targeted sample. The resulting sample size was 20 projects from 15 firms.

The data was checked twice. Once, when entered into SPSS to ensure that no typing errors had been made and a second time, by running the maximums and minimums for each variable to ensure that they were all within the anchors of the given scales. This also tested for outliers.

6.1.1 – Important CE Practices

Respondents that passed the screening criteria were asked to identify from a list of CE practices, which ones they perceived to be important for reducing the time needed to develop new products (Appendix XIV, question 5).

The t-test is used to examine which variables are perceived to be important. Those variables that are significantly greater than the mid-point (3) of the survey scale are statistically significant and important in reducing NPD cycle time. The parameter is set to three, the mid-point on the survey scale, indicating a medium level of importance.

According to the results of the t-test for the 20 projects included in the sample, all of the practices are significant at $p \leq 0.05$. At the $p \leq 0.01$ level, the null hypothesis is also rejected for all practices except for customer/supplier integration as illustrated in Table 6.1.

Table 6.1 – Importance of CE Practices for Reducing Cycle Time[49]

VARIABLE	DESCRIPTION	MEAN	Sig. (two-tailed)	PRACTICE GROUPING
CFT_RT	Cross-functional teams	4.55	.000**	People
DFM_RT	Design for manufacturing	4.35	.000**	Formal Methods
PM_RT	Project management	4.30	.000**	Process
QFD_RT	Quality function deployment	4.21	.000**	Formal Methods
SIMU_RT	Simulation	4.05	.000**	Tools and Techniques
TMDEV_RT	Team development	4.00	.000**	People
COMPU_RT	Computers/Networks	4.00	.000**	Tools and Techniques
CAD_RT	Computer-aided design	3.95	.001**	Tools and Techniques
DOE_RT	Design of experiments	3.90	.001**	Formal Methods
FRMPR_RT	Formal proceedures	3.85	.000**	Process
COLOC_RT	Co-location	3.80	.000**	People
FRMTB_RT	Formal team briefings	3.70	.001**	Process
CAM_RT	Computer-aided manufacturing	3.70	.007**	Tools and Techniques
TMLEA_RT	Team leadership	3.60	.001**	People
REWRD_RT	Rewards and recognition	3.60	.002**	People
FMEA_RT	Failure modes and effect analysis	3.60	.007**	Formal Methods
ORGRE_RT	Organizational redesign	3.55	.004**	Process
CSINT_RT	Customer/Supplier Integration	3.45	.070*	Tools and Techniques

*Significant at $p \leq 0.05$. **Significant at $p \leq 0.01$

All of the practices, as seen in Table 6.1, are between somewhat important and extremely important. They are ranked by their level of importance, which is based on their mean scores. The top three most important practices are cross-functional teams (people practice), DFM (formal method) and project management (process practice).

6.2 – Results to the Research Questions

As discussed in Section 3.4, the model for this research is based on the premise that the relationship between CE practices and NPD cycle time is moderated by the level of newness of the new product or innovation. The research questions focus on the relationship between the practices and cycle time, in addition to any changes in results due to the moderating variable.

[49] In order to use the two-tailed results to reject or accept the null hypothesis, significance levels for those variables which appear to be insignificant are divided by 2.

The Moderating Variable

As stated earlier, the moderating variable had to do with the type of innovation that took place at the organization. Type of innovation refers to incremental and radical innovation. Radical innovation is defined as a breakthrough that involves the creation of entirely new products and sometimes new markets. It entails a high degree of technological and market uncertainty and possibly intense development and commercialization challenges. Incremental innovation, on the other hand, involves much less uncertainty and risk as it builds upon previous or existing products of the firm, where the markets and technology are less ambiguous.

In Question 6 of the survey (Appendix XIV), respondents were asked to indicate whether or not the product for which they were responding was:

a) Entirely new to the firm
b) Significantly modified/improved over a previous/existing product of the firm; or
c) A minor modification to a previous/existing product of the firm.

These three categories distinguish the level of newness of the innovation. The first category is used to describe the product as a radical innovation and the second option categorizes it to be an incremental innovation. The third option is taken as neither an incremental or radical innovation; and is not addressed in this research.

Of the 20 responses collected from 15 firms, there were a total of 14 respondents that indicated their products were part of incremental innovation and 6 respondents that satisfied the condition for the radical innovation group. None of respondents indicated that their product was a minor modification to a previous/existing product of the firm.

The following results are presented for the entire sample and then separated by the two types of innovation. The moderating variable is used to determine if the practices have differing effects NPD cycle time reduction.

6.2.1 – Frequency of Use of CE Practices

The first research question of this study involves determining which CE practices are frequently used in NPD projects of Canadian Electronic Parts and Components companies. In the survey (Appendix XIV), question 7 asked respondents to indicate, on a scale from 1 (not used at all) to 5 (used extensively) the extent to which they used the provided list of CE practices in the overall development of their products.

A t-test is used to test the frequency of use of the practices and determine for which practices are significantly greater than the mid-point (3) of the survey scale and thus statistically significant in terms of frequency of use for the $p \leq 0.01$ and $p \leq 0.05$ levels.

According to the results of the t-test as shown in Table 6.2, there are a total of twelve significant practices. Two practices are significant at the $p \leq 0.05$ level (denoted with one asterix) and ten practices are significant at the $p \leq 0.01$ level (denoted with two asterix). Moreover, Table 6.2 provides a ranking of the practices by average frequency of use.

Table 6.2 – Frequency of Use of CE Practices

VARIABLE	DESCRIPTION	MEAN	Sig. (two-tailed)	PRACTICE GROUPING
PM_U	Project management	4.05	.000**	Process
COMPU_U	Computers/Networks	4.05	.000**	Tools and Techniques
COLOC_U	Co-location	4.00	.000**	People
CFT_U	Cross-functional teams	4.00	.000**	People
CAD_U	Computer-aided design	3.90	.001**	Tools and Techniques
DFM_U	Design for manufacturing	3.84	.002**	Formal Methods
SIMU_U	Simulation	3.80	.003**	Tools and Techniques
TMLEA_U	Team leadership	3.79	.000**	People
FRMTB_U	Formal team briefings	3.65	.002**	Process
FRMPR_U	Formal proceedures	3.45	.016**	Process
QFD_U	Quality function deployment	3.45	.095*	Formal Methods
TMDEV_U	Team development	3.40	.042*	People
CAM_U	Computer-aided manufacturing	3.30	.343	Tools and Techniques
DOE_U	Design of experiments	3.30	.285	Formal Methods
CSINT_U	Customer/Supplier Integration	3.21	.360	Process
FMEA_U	Failure modes and effect analysis	3.20	.464	Formal Methods
REWRD_U	Rewards and recognition	2.90	.577	People
ORGRE_U	Organizational redesign	2.70	.186	Process

*Significant at $p \leq 0.05$. **Significant at $p \leq 0.01$

The most frequently used practices were CFT and co-location (people practices), project management (process practice), and computers/networks and computer-aided-design (tools and techniques).

The six practices that were not found to be significant in terms of frequency of use for developing new or significantly improved products included: rewards or recognition (people practice), customer/supplier integration (process practice), organizational redesign (process practice), CAM (tools and techniques), DOE (formal methods), and failure effects and mode analysis (formal methods).

Using a correlation matrix it is possible to determine which practices are most likely to be used together to reduce NPD cycle time. The correlation analysis of the practices, as seen in Table 6.3, shows the measures of association or the strengths of the relationships among the CE practices.

TABLE 6.3 – CE Practices Commonly Used Together

Variables	DESCRIPTION	Pearson Correlation	Sig.
CAM_U and CAD_U	Computer-aided manufacturing and Computer-aided design	.804	.000**
COMP_U and CAD_U	Computer/Networks and Computer-aided design	.723	.000**
COMP_U and CAM_U	Computers/Networks and Computer-aided manufacturing	.706	.001**
CAD_U and SIM_U	Computer-aided design and simulation	.679	.001**
PM_U and TMLEA_U	Project management and team leadership	.626	.004**
FMEA_U and DFM_U	Failure modes and effect analysis and design for manufacturing	.608	.006**
FMEA_U and DOE_U	Failure mode and effects analysis and design of experiments	.607	.005**
PM_U and QFD_U	Project management and quality function deployment	.589	.006**
FMEA_U and QFD_U	Failure mode and effects analysis and qualify function deployment	.583	.007**
QFD_U and TMDEV_U	Quality function deployment and team development	.582	.007**
PM_U and DOE_U	Project management and design of experiments	.567	.009**
PM_U and FRMTB_U	Project management and formal team briefings	.552	.012*
FMEA_U and ORGRE_U	Failure mode and effects analysis and organizational redesign	.548	.012*
TMLEA_U and REWRD_U	Team leadership and Reward and recognition	.537	.018*
ORGRE_U and CSINT_U	Organizational redesign and Customer/Supplier integration	.526	.021*
CAM_U and SIM_U	Computer-aided manufacturing and Simulation	.513	.021*
DOE_U and TMDEV_U	Design of experiments and Team development	.505	.023*
FMEA_U and TMDEV_U	Failure mode and effects analysis and Team development	.504	.024*
FMEA_U and CAM_U	Failure mode and effects analysis and Computer-aided manufacturing	.504	.024*
PM_U and FMEA_U	Project management and Failure mode and effects analysis	.500	.025*
QFD_U and ORGRE_U	Quality function deployment and Organizational redesign	.499	.029
ORGRE_U and CAM_U	Organizational redesign and Computer-aided manufacturing	.499	.025
ORGRE_U and DFM_U	Organizational redesign and design for manufacturing	.499	.029
COMP_U and ORGRE_U	Computers/Networks and Organizational redesign	.494	.027
PM_U and CFT_U	Project management and Cross-functional teams	.480	.032
QFD_U and SIM_U	Quality function deployment and Simulation	.470	.037
QFD_U and DOE_U	Qualify function deployment and Design of experiments	.464	.039
FRMTB_U and TMDEV_U	Formal team briefings and Team development	.458	.042
PM_U and ORGRE_U	Project management and Organizational redesign	.453	.045
PM_U and TMDEV_U	Project management and Team development	.452	.045
COMP_U and SIM_U	Computers/Networks and Simulation	.450	.046

*Significant at $p \leq 0.05$. **Significant at $p \leq 0.01$

The results show that there are differing degrees of association between the practices. There are a total of twenty significant correlations. Eleven of these correlations are significant at the $p \leq 0.01$ level. The other nine correlations are significant at the $p \leq 0.05$ level.

The Pearson coefficients range between 0.500 and 0.804, indicating moderately to high correlation between the practices. There are no negative Pearson correlation coefficients for frequency of use. A negative coefficient would indicate those practices that are least likely to be used together. In other words, the use of a given practice means that another practice will not be used in its company.

6.2.2 – Use of Practices for Incremental and Radical Innovation

As explained earlier, the data is analyzed in three separate parts. The first part presents the results for the sample as a whole. The second part presents the individual results for those respondents who indicated that they were working either on incremental innovation or on radical innovation.

By separating the two groups from one another, it is possible to determine if the practices have different effects on reducing NPD cycle time (i.e. Time-to-Market, Concept-to-Customer Time, and Development Time) when type of innovation differs.

a) Results for Incremental Innovation

According to the results of the t-test as seen in Table 4, there are a total of ten practices that are significant in terms of frequency of use for incremental innovation; five are significant at the $p \leq 0.05$ level and the other five are significant at the $p \leq 0.01$ level. These practices are "used somewhat" to "used extensively".

Table 6.4, below, provides a ranking of the significant practices by their level of frequency of use, based on their mean scores.

Table 6.4 – Frequency of Use of CE Practices: Incremental Innovation

VARIABLE	DESCRIPTION	MEAN	Sig. (two-tailed)	PRACTICE GROUPING
COMPU_U	Computers/Networks	4.07	.000**	Tools and Techniques
CFT_U	Cross-functional teams	4.00	.000**	People
PM_U	Project management	4.00	.000**	Process
COLOC_U	Co-location	3.86	.005**	People
DFM_U	Design for manufacturing	3.86	.017*	Formal Methods
CAD_U	Computer-aided design	3.79	.035*	Tools and Techniques
FRMTB_U	Formal team briefings	3.71	.012**	Process
SIMU_U	Simulation	3.71	.045*	Tools and Techniques
TMLEA_U	Team leadership	3.62	.005**	People
FRMPR_U	Formal proceedures	3.43	.054*	Process
CAM_U	Computer-aided manufacturing	3.43	.336	Tools and Tecqniques
QFD_U	Quality function deployment	3.43	.212	Formal Methods
DOE_U	Design of experiments	3.29	.414	Formal Methods
TMDEV_U	Team development	3.29	.218	People
FMEA_U	Failure modes and effect analysis	3.21	.568	Formal Methods
CSINT_U	Customer/Supplier Integration	3.07	.775	Process
REWRD_U	Rewards and recognition	2.79	.336	People
ORGRE_U	Organizational redesign	2.64	.208	Process

*Significant at $p \leq 0.05$. **Significant at $p \leq 0.01$

As seen in Table 6.4, the three most frequently used practices are computers/networks (tools and techniques), CFT (people practice) and project management (process practice). The six practices that were not found to be significant in terms of frequency of use for developing new products included: team development (people practice), rewards and recognition (people practice), customer/supplier integration (process practice), organizational redesign (process practice), CAM (tools and techniques), DOE (formal methods), QFD (formal methods) and failure effects and mode analysis (formal methods). All but the QFD were not significant when the t-test was applied to the sample as a whole.

Using a correlation matrix, as seen in Table 6.5, below, it is possible to determine which practices are most likely to be used together to reduce NPD cycle time for incremental innovation.

TABLE 6.5 – CE Practices Used Together: Incremental Innovation

Variables	DESCRIPTION	Pearson Correlation	Sig.
CAD_U and CAM_U	Computer-aided design and Computer-aided manufacturing	.864	.000**
TMDEV_U and FRMTB_U	Team development and Formal team briefings	.831	.000**
CAD_U and COMPU_U	Computer-aided design and Computers/networks	.754	.003**
CAM_U and COMPU_U	Computer-aided manufacturing and Computers/networks	.710	.007**
ORGRE_U and QFD_U	Organizational redesign and Quality function deployment	.704	.007**
CAD_U and SIMU_U	Computer-aided design and Simulation	.696	.008**
REWRD_U and DOE_U	Rewards and recognition and Design of experiments	.694	.008**
TMLEA_U and PM_U	Team leadership and Project management	.676	.016*
ORGRE_U and FMEA_U	Organizational redesign and Failure mode and effects analysis	.670	.012*
FMEA_U and DOE_U	Failure modes and effect analysis and Design of experiments	.648	.017*
FMEA_U and DFM_U	Failure mode and effects analysis and Design for manufacturing	.634	.020*
FRMTB_U and PM_U	Formal team briefings and Project management	.623	.023*
PM_U and FMEA_U	Project management and Failure modes and effect analysis	.616	.025*
COLOC_U and COMPU_U	Co-location and Computers/networks	.597	.0318
CAM_U and SIMU_U	Computer-aided manufacturing and Simulation	.586	.035*
FMEA_U and QFD_U	Failure mode and effects analysis and Quality function deployment	.575	.040*
PM_U and QFD_U	Project management and Quality function deployment	.572	.041*
FRMTB_U and DFM_U	Formal team briefings and Design for manufacturing	.564	.045*
ORGRE_U and DFM_U	Organizational redesign and Design for manufacturing	.563	.045*

*Significant at p≤0.05. **Significant at p≤0.01

The results show that there are nineteen statistically significant relationships between the practices; they range from moderate to high correlation with one another. Seven of these correlations are significant at the p≤0.01 level. The other twelve correlations are significant at the p≤0.05 level. The Pearson coefficients vary between

0.563 and 0.864. Certain practices have significantly to moderately strong relationships with more variables than others. When examining the use of FMEA (formal method), the result shows it is correlated with six other variables. Other variables that are significantly correlated with at least three other practices include: project management (process), CAD (tool and technique), CAM (tool and technique), QFD (formal method), formal team briefings (process), computers/networks (tool and technique), organizational redesign (process), simulation (formal method), and DFM (formal method).

b) Results for Radical Innovation

According to the results of the t-test as seen in Table 6.6, there are a total of ten practices that are significant in terms of frequency of use for radical innovation; three are significant at the p≤0.05 level and eight are significant at the p≤0.01 level. These practices are "used somewhat" to "used extensively". Table 6.6 provides a ranking of the significant practices by average frequency of use.

Table 6.6 – Frequency of Use of CE Practices: Radical Innovation

VARIABLE	DESCRIPTION	MEAN	Sig. (two-tailed)	PRACTICE GROUPING
COLOC_U	Co-location	4.33	.001**	People
CAD_U	Computer-aided design	4.17	.001**	Tools and Techniques
TMLEA_U	Team leadership	4.17	.013**	People
PM_U	Project management	4.17	.001**	Process
COMPU_U	Computers/Networks	4.00	.012**	Tools and Techniques
SIMU_U	Simulation	4.00	.012**	Tools and Techniques
CFT_U	Cross-functional teams	4.00	.076*	People
DFM_U	Design for manufacturing	3.80	.016**	Formal Methods
TMDEV_U	Team development	3.67	.102	People
CSINT_U	Customer/Supplier Integration	3.60	.305	Formal Methods
QFD_U	Quality function deployment	3.50	.296	Process
FRMTB_U	Formal team briefings	3.50	.076*	Tools and Techniques
FRMPR_U	Formal proceedures	3.50	.203	Tools and Techniques
DOE_U	Design of experiments	3.33	.530	Formal Methods
REWRD_U	Rewards and recognition	3.17	.611	Process
FMEA_U	Failure modes and effect analysis	3.17	.611	People
CAM_U	Computer-aided manufacturing	3.00	1.000	Formal Methods
ORGRE_U	Organizational redesign	2.83	.695	People

*Significant at p≤0.05. **Significant at p≤0.01

As seen in Table 6.6, several practices tied for the top three most frequently used practices. These practices include co-location, team leadership, and CFT (people practices), project management (process practice), computers/networks, computer-aided design, and simulation (tools and techniques).

The six practices that were not found to be significant in terms of frequency of use include: rewards and recognition (people practice), team development (people practice), customer/supplier integration (process practice), formal procedures (process practice), organizational redesign (process practice), CAM (tools and techniques), DOE (formal methods), QFD (formal methods) and FMEA (formal methods). These results are very similar to the overall results of the entire sample and for incremental innovation.

Using a correlation matrix, as seen in Table 6.7, below, the practices which are most likely to be used together to reduce NPD cycle time specifically for radical innovation are identified.

TABLE 6.7 – CE Practices Used Together: Radical Innovation

Variables	DESCRIPTION	Pearson Correlation	Sig.
CAM_U and COMPU_U	Computer-aided manufacturing and Computers/Networks	1.000	.000**
DOE_U and CSINT_U	Design of experiments and Customer/Supplier integration	.945	.004**
DOE_U and QFD_U	Design of experiments and Quality function deployment	.899	.006**
REWRD_U and CSINT_U	Rewards and recognition and Customer/Supplier integration	-.870	.024*
CAD_U and COMPU_U	Computer-aided design and Computers/Networks	.849	.016*
CAD_U and CAM_U	Computer-aided design and Computer-aided manufacturing	.849	.016*
SIMU_U and QFD_U	Simulation and Quality function deployment	.849	.016*
CFT_U and ORGRE_U	Cross-functional teams and Organizational redesign	.833	.020*
REWRD_U and FRMPR_U	Rewards and recognition and Formal procedures	-.801	.031*
TMDEV_U and FRMPR_U	Team development and Formal procedures	.801	.031*
DOE_U and FRMPR_U	Design of experiments and Formal procedures	.789	.035*
FRMTB_U and FMEA_U	Formal team briefings and Failure mode and effects analysis	-.766	.045*

*Significant at $p \leq 0.05$. **Significant at $p \leq 0.01$

The results show that there are twelve statistically significant relationships between the practices; they share a high correlation with one another. Three of these correlations are significant at the $p \leq 0.01$ level. The other nine correlations are significant at the $p \leq 0.05$ level.

The absolute values of the Pearson coefficients vary between 0.766 and 1.000. There are also some strongly negative relationships, suggesting that certain practices are unlikely to be used with other practices. For example, the more likely NPD managers use rewards and recognitions for reducing NPD cycle time for radical innovation, the less likely they will use customer/supplier integration or formal procedures. The same type of result occurs between formal team briefings and the use of FMEA.

The high correlation results are alarming. In part, they can be due to the extremely small sample size of the radical innovation group (n=7). In other cases such as with computers/networks and computer aided systems, high correlation (correlation-coefficient of 1) is due to co-linearity.

c) Comparison of results between incremental and radical innovation

Table 6.8, below, provides a summary of those practices that NPD managers are most likely to use for reducing NPD cycle time for each type of innovation. The bold depicts those practices that are statistically significant at the $p \leq 0.05$ level. Table 6.8 also reveals those differences between the means for radical and incremental innovation that are statistically significant differences. These statistical differences were identified through use of a t-test, which examines the equality of the means.

Between the two groups, there is only one practice that is not statistically significant in terms of frequency of use (i.e., having a mean that is significantly greater than the mid-point (3) of the five-point survey scale) for both types of innovation. This practice is team development; it was significantly greater than the mid-point for radical but not incremental innovation. The variable, formal procedures, was significant in terms of frequency of use for incremental innovation but not for radical innovation. Results from the t-test for equality of means demonstrate that none of the mean differences between radical and incremental innovation are statistically significant. In other words, statistically, none of the CE practices are used more frequently for one type of innovation over the other, even though the means for practices used for radical innovation appear higher than for incremental innovation.

Table 6.8 – Differences in Frequency of Use of CE Practices by Type of Innovation

VARIABLE	INCREMENTAL MEANS	RADICAL MEANS	DIFFERENCE IN MEANS	T-TEST FOR EQUALITY OF MEANS SIG. (two-tailed)
TMLEA_U	**3.62**	**4.17**	-.55	.120
CSINT_U	3.07	3.60	-.53	.312
COLOC_U	**3.86**	**4.33**	-.47	.267
CAM_U	3.43	3.00	.43	.539
REWRD_U	2.79	3.17	-.38	.335
CAD_U	**3.79**	**4.17**	-.38	.481
TMDEV_U	3.29	3.67	-.38	.355
SIMU_U	**3.71**	**4.00**	-.29	.593
FRMTB_U	**3.71**	**3.50**	.21	.603
ORGRE_U	2.64	2.83	-.19	.701
PM_U	**4.00**	**4.17**	-.17	.518
QFD_U	3.43	3.50	-.07	.902
COMPU_U	**4.00**	**4.07**	-.07	.838
FRMPR_U	**3.43**	3.50	-.07	.853
DFM_U	**3.86**	**3.80**	.06	.918
DOE_U	3.29	3.33	-.04	.939
FMEA_U	3.21	3.17	.04	.938
CFT_U	**4.00**	**4.00**	0	1.000

Bold indicates statistical significance at p≤0.05 or p≤0.01 levels when testing the difference between the mean and the mid-point (3) of the survey scale. *Indicates the statistically significant differences between the means for radical and incremental innovation.

Despite the lack of statistical difference in the means, it is still meaningful to examine these differences. The fact that the means are higher for radical innovation could signify that the practices are actually used more extensively for radical than for incremental innovation. In particular, practices used more frequently for radical innovation include team leadership (people practice), customer/supplier integration (process practice) and co-location (people practice). It is interesting to examine these differences as the lack of statistical significance might result from the small sample size.

6.2.3 – Effectiveness of Practices in Reducing NPD Cycle Time

The second research question of this study involves determining which CE practices are most effective in reducing the time needed to develop new of significantly improved products. In the survey (Appendix XIV), question 11 asked respondents to indicate, on a scale from 1 (did not reduce time at all) to 5 (extensively reduced time) the extent to which CE practices actually reduced the time needed to develop the new or significantly improved product. This is based on the perception of NPD managers.

Question 11, however, is limited, in that respondents were asked to answer only for the reduction of Time-to-Market. Recalling from section 2.3.1, NPD cycle time was defined in terms of three different measures of time including; Time-to-Market, Concept-to-Customer Time, and Development Time (see section 2.3.1.3 for definitions). Questions 8, 9 and 10 of the survey can also be used to determine the effectiveness of CE practices in reducing the NPD cycle time. These three questions asked respondents to estimate the amount of time reduction achieved for each of the three measures of time as a result of using CE practices.

The following sections 6.4.1 and 6.4.2 effectiveness of practices in reducing NPD cycle time in two ways. The first one addresses the findings from question 11 indicating which practices are effective in reducing Time-to-Market. The second addresses the amount of reduction of NPD cycle time due to using CE practices (from question 8, 9 and 10). While small sample size limit any meaningful interpretation of correlation results between the percentage of time reduced as identified through questions 8, 9 and 10 and the individual practices, results do show that use of CE practices, overall, do contribute to the reduction of Time-to-Market, Concept-to-Customer Time and Development Time.

6.2.3.1 – Perceived Effectiveness of Practices in Reducing Time-to-Market

In order to determine which practices, respondents believe to be most effective in reducing Time-to-Market the t-test is used. For those practices that are not significantly greater than the mid-point (3) of the survey scale, means the respondents do not believe the practices contribute to the reduction of Time-to-Market.

According to the results of the t-test as seen in Table 6.9, there are a total of eleven significant practices. Three of the practices are significant at the $p \leq 0.01$ level and eight practices are significant at the $p \leq 0.05$ level. These practices are perceived to be somewhat effective to extremely effective and differ significantly from the mid-point of the scale. Table 6.9 provides a ranking of the practices by their perceived level of effectiveness, based on their mean scores.

Table 6.9 – Effectiveness of CE Practices in Reducing Time-to-Market

VARIABLE	DESCRIPTION	MEAN	Sig. (two-tailed)	PRACTICE GROUPING
PM_A	Project management	4.05	.000**	Process
CFT_A	Cross-functional teams	3.70	.001**	People
DFM_A	Design for manufacturing	3.68	.011*	Formal Methods
CAD_A	Computer-aided design	3.55	.037*	Tools and Techniques
SIMU_A	Simulation	3.55	.037*	Tools and Techniques
COMPU_A	Computers/Networks	3.50	.056*	Tools and Techniques
TMLEA_A	Team leadership	3.45	.009**	People
COLOC_A	Co-location	3.35	.069*	People
FRMTBR_A	Formal team briefings	3.30	.083*	Process
FRMPR_A	Formal proceedures	3.25	.204	Process
CAM_A	Computer-aided manufacturing	3.22	.494	Tools and Techniques
QFD_A	Quality function deployment	3.11	.650	Formal Methods
DOE_A	Design of experiments	3.05	.789	Formal Methods
CSINT_A	Customer/Supplier Integration	2.95	.825	Process
FMEA_A	Failure modes and effect analysis	2.84	.482	Formal Methods
TMDEV_A	Team development	2.80	.385	People
REWRD_A	Rewards and recognition	2.65	.069†	People
ORGRE_A	Organizational redesign	2.60	.028†	Process

*Significant at $p \leq 0.05$. **Significant at $p \leq 0.01$. †Significantly less than the mid-point (3) of survey scale.

As seen in Table 6.9, the three most frequently used practices are project management (process practice), CFT (people practice) and DFM (formal method).

The seven practices that were not found to be significantly effective for reducing Time-to-Market included: team development (people practice), customer/supplier integration (process practice), formal procedures (process practice), CAM (tools and techniques), DOE (formal methods), and FMEA (formal methods) and QFD (formal methods).

Results of T-Test Applied to Research Hypotheses

The above test provides the results needed to reject or not reject the research hypotheses as identified in Section 3.4.1, which pertain to Time-to-Market. Table 6.10, below, indicates which hypotheses are not rejected (NR) based on the significant results of the t-test for the perception of respondents regarding practices which reduce Time-to-Market (Q.11 as seen in Table 6.13). The t-test identified those practices that whose means for effectiveness in reducing Time-to-Market was significantly greater than the mid-point (3) of the five-point survey scale.

Table 6.10 – Hypotheses Not Rejected Due to Significant T-Test Results

(as per Section 3.4.1	Hypotheses	T-test results for Q.11 (Time-to-Market only)
1a1	Adoption of co-location reduces the Time-to-Market of new products	NR
1a2	Adoption of cross-functional teams reduces the Time-to-Market of new products	NR
1a3	Adoption of team development reduces the Time-to-Market of new products	NR
1a4	Adoption of team leadership reduces the Time-to-Market of new products	NR
1a5	Adoption of reward and recognition reduces the Time-to-Market of new products	NR
2a1	Adoption of customer/supplier integration reduces the Time-to-Market of new products	NR
2a2	Adoption of formal team briefings reduces the Time-to-Market of new products	NR
2a3	Adoption of organizational redesign reduces the Time-to-Market of new products	NR
2a4	Adoption of project management reduces the Time-to-Market of new products	NR
3a1	Adoption of computers/networks reduces the Time-to-Market of new products	NR
3a2	Adoption of computer-aided design reduces the Time-to-Market of new products	NR
3a3	Adoption of computer-aided manufacturing reduces the Time-to-Market of new products	NR
3a4	Adoption of simulation reduces the Time-to-Market of new products	NR
4a1	Adoption of design of experiments reduces the Time-to-Market of new products	NR
4a2	Adoption of design for manufacturing reduces the Time-to-Market of new products	NR

Table 6.10 includes only those hypotheses where the null hypothesis is rejected by at least one of the two tests. Based on the first test, the results show that there are only four cases where the null hypothesis was rejected. In these cases, correlations between the practice and one of the three measures of cycle time were found. For the second test, on the other hand, the only cases where the null hypothesis was *not* rejected were for formal procedures (process practice), QFD (formal method) and FMEA (formal method).

With regards to the three measures of cycle time, Time-to-Market was the only time measure for which the ability of the individual practices to reduce NPD cycle time could be assessed. Again, this has to do with the fact that one of the survey questions pertained directly to it and that there is insufficient data to test through correlation analysis the effectiveness of each individual practice in reducing NPD cycle time. According to NPD managers, however, there is evidence that indicate that CE practices, overall, can contribute to the reduction of Development Time and Concept-to-Customer as explained in section 6.4.2.

6.2.3.2 – Effectiveness of Practices in Reducing Time-to-Market by Type of Innovation

a) Results for Incremental Innovation

When examining the effectiveness of CE practices for incremental innovation, the results of the t-test, as seen in Table 6.11, show that there are four statistically significant practices. Three of these practices are significant at the $p \leq 0.01$ level and the fourth is significant at the $p \leq 0.05$ level. Not all of these practices have means greater than the mid-point of the scale. Two of the significant practices have average scores indicating that they are less than somewhat effective in reducing Time-to-Market.

Table 6.11, below, provides a ranking of the practices by their level of effectiveness, based on their mean scores.

Table 6.11 – Effectiveness of CE Practices in Reducing Time-to-Market for Incremental Innovation

VARIABLE	DESCRIPTION	MEAN	Sig. (two-tailed)	PRACTICE GROUPING
PM_A	Project management	3.86	.000**	Process
CFT_A	Cross-functional teams	3.79	.001**	People
COMPU_A	Computers/Networks	3.50	.131	Tools and Techniques
DFM_A	Design for manufacturing	3.46	.139	Formal Methods
CAD_A	Computer-aided design	3.43	.165	Tools and Techniques
SIMU_A	Simulation	3.29	.302	Tools and Techniques
COLOC_A	Co-location	3.29	.165	People
FRMPR_A	Formal proceedures	3.21	.336	Process
FRMTBR_A	Formal team briefings	3.21	.336	Process
CAM_A	Computer-aided manufacturing	3.21	.568	Tools and Techniques
TMLEA_A	Team leadership	3.21	.189	People
DOE_A	Design of experiments	3.00	1.000	Formal Methods
QFD_A	Quality function deployment	3.00	1.000	Formal Methods
FMEA_A	Failure modes and effect analysis	2.77	.389	Formal Methods
CSINT_A	Customer/Supplier Integration	2.71	.218	Tools and Techniques
TMDEV_A	Team development	2.64	.208	Process
ORGRE_A	Organizational redesign	2.57	.082†	Process
REWRD_A	Rewards and recognition	2.43	.006†	People

*Significant at $p \leq 0.05$. **Significant at $p \leq 0.01$. †Significantly less than the mid-point (3) of survey scale.

As seen in Table 6.11, of the four significant practices CFT and project management tied for first place, organizational redesign came second and last was rewards and recognition.

b) Results for Radical Innovation

According to the results of the t-test as seen in Table 6.12 there are only five significant practices. Two of these practices are significant at the $p \leq 0.01$ level and the other three of the practices are significant at the $p \leq 0.05$ level. Not all of these practices have means greater than the mid-point of the scale. These practices are between somewhat effective and extremely effective in reducing Time-to-Market. Their mean scores are higher than the mid-point of the scale.

Table 6.12 provides a ranking of the practices by their level of effectiveness, based on their mean scores.

Table 6.12 – Effectiveness of the CE Practices in Reducing Time-to-Market: Radical Innovation

VARIABLE	DESCRIPTION	MEAN	Sig. (two-tailed)	PRACTICE GROUPING
PM_A	Project management	4.50	.001**	Process
DFM_A	Design for manufacturing	4.17	.034*	Formal Methods
SIMU_A	Simulation	4.17	.058*	Tools and Techniques
TMLEA_A	Team leadership	4.00	.012**	People
CAD_A	Computer-aided design	3.83	.141	Tools and Techniques
COLOC_A	Co-location	3.50	.296	People
CFT_A	Cross-functional teams	3.50	.296	People
COMPU_A	Computers/Networks	3.50	.296	Tools and Techniques
FRMTBR_A	Formal team briefings	3.50	.076*	Process
CSINT_A	Customer/Supplier Integration	3.50	.363	Process
FRMPR_A	Formal proceedures	3.33	.465	Process
QFD_A	Quality function deployment	3.33	.465	Formal Methods
TMDEV_A	Team development	3.17	.695	Process
CAM_A	Computer-aided manufacturing	3.17	.741	Tools and Techniques
REWRD_A	Rewards and recognition	3.17	.695	People
DOE_A	Design of experiments	3.17	.611	Formal Methods
FMEA_A	Failure modes and effect analysis	3.00	1.000	Formal Methods
ORGRE_A	Organizational redesign	2.67	.175	Process

*Significant at $p \leq 0.05$. **Significant at $p \leq 0.01$.

As seen in Table 6.12, of the five significant practices project management came first, DFM and simulation tied for second place, team leadership was third and last was formal team briefings. The three most effective practices for reducing Time-to-Market for radical innovation are project management (process practice), DFM (formal method), simulation (formal method), and team leadership (people practice).

There are more practices that are significantly effective in reducing Time-to-Market for radical innovation than for incremental innovation.

c) Comparison of results between incremental and radical innovation

Table 6.13 provides a summary of the practices NPD managers perceived to be most effective for reducing Time-to-Market, separated by type of innovation. The bold depicts those practices that are statistically significant at the $p \leq 0.05$ level. Table 6.13 also reveals those differences between the means for radical and incremental innovation that are statistically significant differences. These statistical differences were identified through use of a t-test, which examines the equality of the means.

Those practices whose effectiveness varies the most by type of innovation include; simulation (formal method), team leadership (people practice), customer/supplier integration (process practice), rewards and recognition (people practice), design-for-manufacturing (formal method), project management (process practice), and team development (people practice).

Despite the variations, however, between means for effectiveness for incremental and radical innovation, the means for only three practices were statistically significant differences based on the results from the t-test for equality of means. These practices include simulation, customer/supplier integration and project management.

Table 6.13 – Differences in Effectiveness of CE Practices by Type of Innovation

VARIABLE	INCREMENTAL MEANS	RADICAL MEANS	DIFFERENCE IN MEANS	T-TEST FOR EQUALITY OF MEANS SIG. (two-tailed)
SIMU_A	3.29	**4.17**	-.88	.101
TMLEA_A	3.21	**4.00**	-.79	.014**
CSINT_A	2.71	3.50	-.79	.108
REWRD_A	**2.43**	3.17	-.74	.060*
DFM_A	3.46	**4.17**	-.71	.184
PM_A	**3.86**	**4.50**	-.64	.052*
TMDEV_A	2.64	3.17	-.53	.298
CAD_A	3.43	3.83	-.4	.465
QFD_A	3.00	3.33	-.33	.513
FRMTBR_A	3.21	**3.50**	-.29	.439
CFT_A	**3.79**	3.50	.29	.480
FMEA_A	2.77	3.00	-.23	.639
COLOC_A	3.29	3.50	-.21	.603
DOE_A	3.00	3.17	-.17	.691
FRMPR_A	3.21	3.33	-.12	.783
ORGRE_A	**2.57**	2.67	-0.1	.804
CAM_A	3.21	3.17	.04	.942
COMPU_A	3.50	3.50	0	1.000

Bold indicates statistical significance at $p \leq 0.05$ or $p \leq 0.01$ levels when testing the difference between the mean and the mid-point (3) of the survey scale. *Indicates statistical significance in difference between means for incremental and radical innovation at $p \leq 0.05$ level and ** indicate the same at $p \leq 0.01$ level.

Between the two groups, there is only project management was found to be significantly effective for both types of innovation when testing if the means were significantly greater than the mid-point (3) of the five-point survey scale. There are more significantly effective practices for radical innovation than for incremental innovation (e.g., DFM, simulation, team leadership and formal team briefings). Cross-functional teams was significantly effective for incremental innovation but not for radical innovation.

Results of T-Test Applied to Research Hypotheses

Table 6.14, below, indicates which research hypotheses are not rejected (NR) for incremental and radical innovation, based on the statistically significant differences between the means regarding effectiveness in reducing Time-to-Market for incremental versus radical innovation.

Table 6.14 – Research Hypotheses Not Rejected Due to Significant T-Test Results by Type of Innovation

(as per Section 3.4.1)	Hypotheses	T-Test for Equality of Means for Q.11
5a	Adoption of team leadership reduces the Time-to-Market differently for incremental versus radical innovation	**NR** (mean for radical innovation higher)
5a	Adoption of rewards and recognition reduces the Time-to-Market differently for incremental versus radical innovation	**NR** (mean for radical innovation higher)
5a	Adoption of project management reduces the Time-to-Market differently for incremental versus radical innovation	**NR** (mean for radical innovation higher

As identified earlier, the means for project management regarding effectiveness was significantly greater than the mid-point (3) of the five-point survey scale for both incremental and radical innovation. The mean for team leadership was significantly greater than the mid-point for only radical innovation and the mean for rewards and recognition was not significantly greater than the mid-point for either radical or incremental innovation.

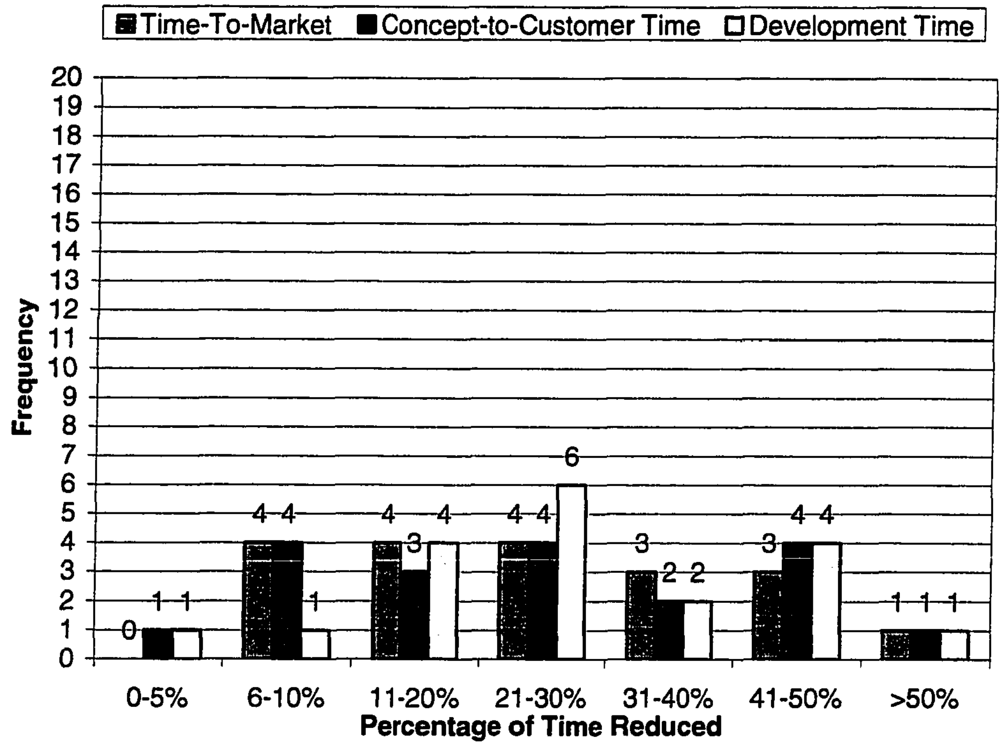
6.2.4 – Effectiveness of Practices in Reducing the Three Time Measures

In order to determine the effectiveness of reducing all three time measures, the practices that were actually used can be correlated with the amount of time reduced for Time-to-Market, Concept-to-Customer Time and Development Time. The significant correlations would indicate which practices contributed to time reduction. When this test was performed, however, the results were difficult to interpret due to the low number of survey responses collected. Thus these results have been excluded from this study.

Since the survey included a question on the perception of managers with regards to the extent to which individual practices reduced Time-to-Market, results regarding practices that reduce that measure of time have been analyzed in the previous section. Results regarding which practices reduce Development Time and Concept-to-Customer, however, could not be obtained and present a gap in this study.

Despite the inability to report on the individual practices that reduced Development time and Concept-to-Customer, the results do indicate that the usage of the CE practices listed have led to reduced time for all three time measures. Figure 6.1 demonstrates the average amount of Time-to-Market, Concept-to-Customer Time, and Development Time that was reduced as a result of using CE practices.

Figure 6.1 – Percentage of the Three Time Measures Reduced



As seen in the figures above, the majority of respondents believed that Time-to-Market, Concept-to-Customer Time and Development Time were reduced by 30% or less, as a result of the CE Practices. Clearly CE practices contributed to time-savings.

On a scale of 7, the average responses for the 20 respondents are shown in Table 6.15 for each of the three time measures.

Table 6.15 – Average Response for Time Reduced by CE Practices

Measures of Time	Description	Mean
TTM_RED	Time-to-Market	4.00
CTCT_RED	Concept-to-Customer Time	3.95
DT_RED	Development Time	4.21

According to the respondents, the use of CE practices reduces all three cycles of time by more than 20% but less than 31% (on 7-point scale 4 is "21-30%). The means suggest that Development Time could potentially be reduced to a larger extent then Time-to-Market and Concept-to-Customer Time as a result of using CE practices.

6.2.4.1 – Effectiveness of Practices in Reducing Three Time Measures by Type of Innovation

As explained earlier the data is analyzed in three separate parts. The first part presents the results for the sample as a whole. The second part presents the individual results for those respondents that identified their product as incremental and then those that identified their product as radical. The incremental innovation group consists of 14 respondents and the radical innovation group consists of 6 respondents.

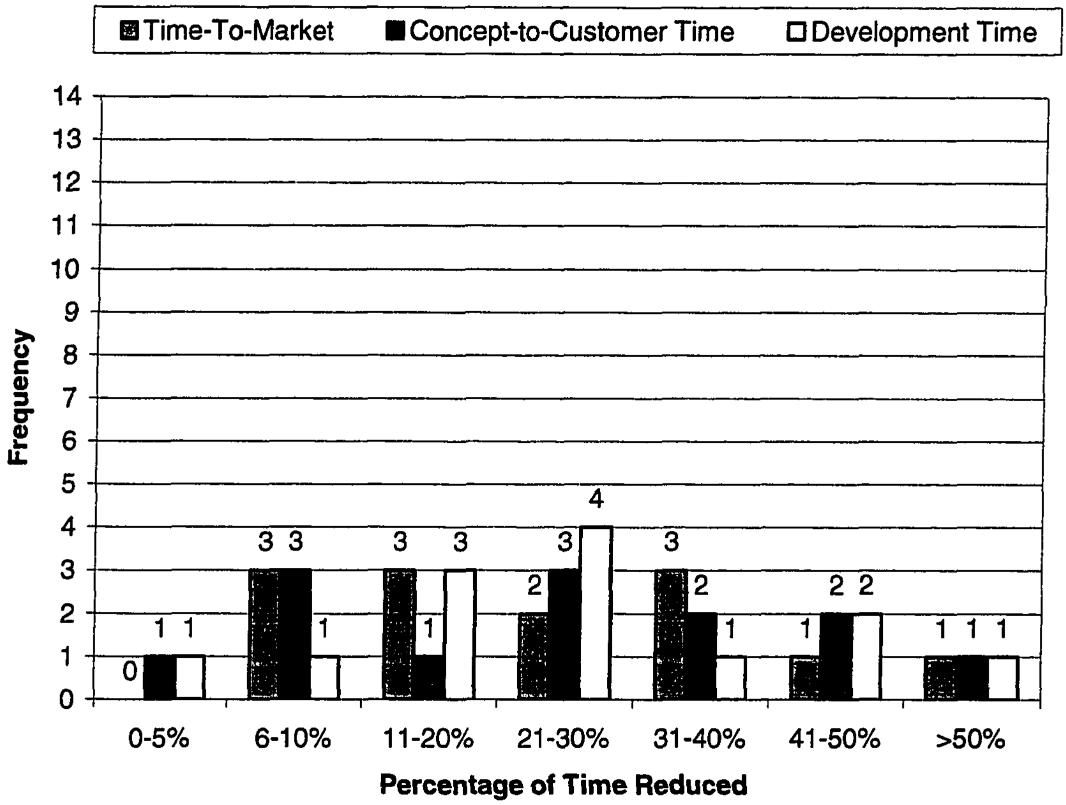
By separating the two groups from one another, it is possible to determine if the effectiveness of the practices in reducing NPD cycle time (i.e. Time-to-Market, Concept-to-Customer Time, and Development Time) differs depending on the type of innovation.

a) Results for Incremental Innovation

As explained earlier, due to the small sample size results for the correlations between the practices and the three measures of time were difficult to interpret. Thus, while this section does not report on the individual practices that reduced the three measures of cycle time for incremental innovation projects, it does show the extent to which the time measures were reduced overall, without reference to any specific practice.

Figure 6.2 demonstrates the average amount of Time-to-Market, Concept-to-Customer Time, and Development Time that was reduced as a result of using CE practices based on the responses of the 14 incremental innovation respondents.

Figure 6.2 – Percentage of All Three Time Measures Reduced: Incremental



As seen in Figure 6.2, the majority of respondents believed that Time-to-Market, Concept-to-Customer Time and Development Time were reduced by 30% or less, as a result of the CE Practices.

On a scale of 7, the average responses for the 14 incremental innovation respondents are shown in Table 6.16 for each of the three time measures.

Table 6.16 – Average Response for Time Reduced: Incremental

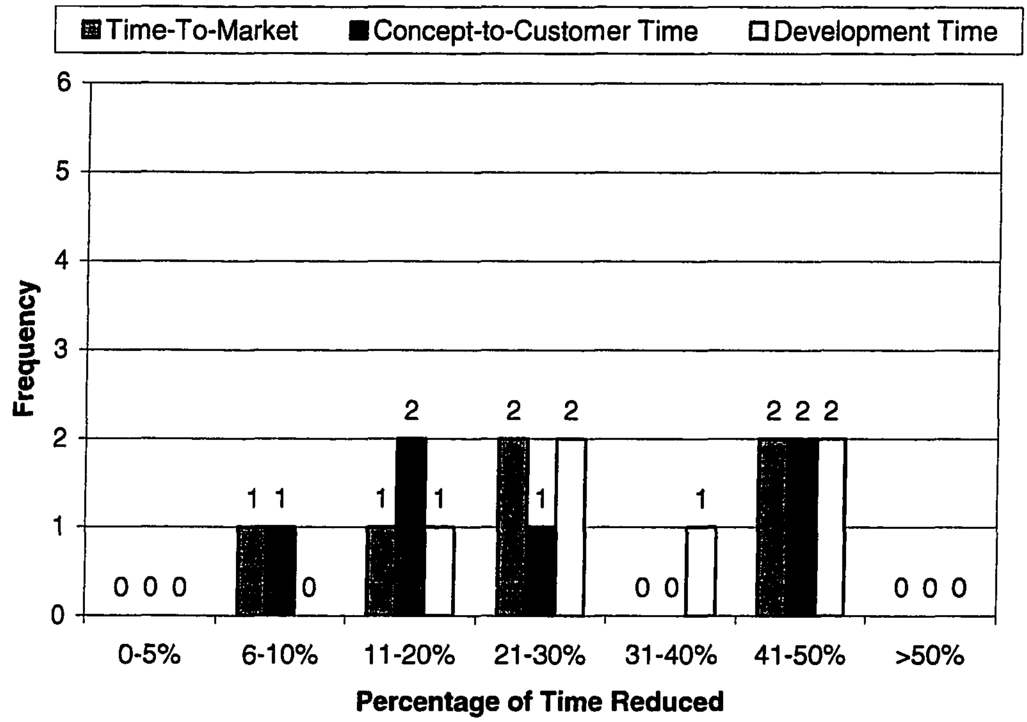
Measures of Time	Description	Mean
TTM_RED	Time-to-Market	3.92
CTCT_RED	Concept-to-Customer Time	3.92
DT_RED	Development Time	4.00

According to the respondents, use of CE practices reduces all three cycles of time by more than 20% but less than 31% (on 7-point scale 4 is "21-30%). The means suggest that Development Time could potentially be reduced to a larger extent then Time-to-Market and Concept-to-Customer Time as a result of using CE practices.

b) Results for Radical Innovation

Figure 6.3 demonstrates the average amount of Time-to-Market, Concept-to-Customer Time, and Development Time that was reduced as a result of using CE practices based on the responses of the 6 radical innovation respondents.

Figure 6.3 – Percentage of All Three Time Measures Reduced: Radical



As seen in Figure 6.3 the majority of respondents believed that Time-to-Market, Concept-to-Customer Time and Development Time were reduced by 21% or more, as a result of the CE Practices.

On a scale of 7, the average responses for the 6 radical innovation respondents are shown in Table 6.17 for each of the three time measures.

Table 6.17 – Average Response for Time Reduced: Radical

Measures of Time	Description	Mean
TTM_RED	Time-to-Market	4.17
CTCT_RED	Concept-to-Customer Time	4.00
DT_RED	Development Time	4.67

According to the respondents, the use of CE practices reduces all three cycles of time by more than 20% but less than 31% (on 7-point scale 4 is "21-30%). The means suggest that Development Time could potentially be reduced to a larger extent then Time-to-Market and Concept-to-Customer Time as a result of using CE practices.

While the means for average reduction in all three cycle times seem higher for radical innovation versus incremental innovation, the differences between their means for the three cycle times were not found to be statistically significant differences.

6.3 – The Gap between Actual Usage and Perceived Usefulness

The third research question examines the gaps, if any, between the results obtained from question 7 of the survey (extent to which practices were used) and question 11 (extent to which practices are perceived to have reduced Time-to-Market) (Appendix XIV). This allows us to examine if the actual usage and perceived performance of CE practices, according to NPD managers, are in alignment with one another.

Earlier in this chapter, the statistical significance of practices actually used and those perceived to reduce time (otherwise known as effective practices) were presented in Table 6.2 and Table 6.6 respectively. Based on the SPSS results presented in those two tables, Table 6.18 is a summary of those practices (in bold) that were found to be significantly greater than the mid-point (3) of the five-point survey scale, regarding the frequency of their use and the extent to which they were effective in reducing Time-to-Market.

Table 6.18 also shows those practices that were frequently used and at the same time effective in reducing Time-to-Market. Using Spearman's Rho, a correlation coefficient, relationships between frequency of use and extent of effectiveness in reducing Time-to-Market are tested. The closer the correlation coefficient is to 1 the more likely an NPD manager that indicated a particular score for frequency of use, also indicated a similar score for effectiveness of Time-to-Market reduction (both on a five-point scale).

Where Spearman Rho is closer to 0 and where it is not statistically significant at either the p≤0.05 or p≤0.01 levels as indicated by the asterix, a gap between use and frequency may be interpreted.

Table 6.18 – Frequently Used Practices versus Effective Practices

Frequently Used Practices (Q7)	Effective Practices (Q11)	Name of Practice	Practice Grouping	Spearman Rho Correlation Coefficient	Sig. (two-tailed)
DOE_U	DOE_A	Design of Experiments	Formal Method	.757	.000**
FRMPR_U	FRMPR_A	Formal Procedures	Process	.707	.000**
CAM_U	CAM_A	Computer-aided manufacturing	Tool and Technique	.701	.001**
CAD_U	**CAD_A**	Computer-aided design	Tool and Technique	.669	.001**
QFD_U	QFD_A	Quality Function Deployment	Formal Method	.636	.003**
ORGRE_U	ORGRE_A	Organizational Redesign	Process	.628	.003**
PM_U	**PM_A**	Project Management	Process	.586	.007**
FMEA_U	FMEA_A	Failure Modes and Effects Analysis	Formal Method	.565	.012**
CSINT_U	CSINT_A	Customer/Supplier Integration	Process	.536	.018**
COMPU_U	**COMPU_A**	Computers/Networks	Tool and Technique	.518	.019**
TMLEA_U	**TMLEA_A**	Team Leadership	People	.464	.045*
DFM_U	**DFM_A**	Design for Manufacturing	Formal Method	.457	.056*
REWRD_U	REWRD_A	Rewards and Recognition	People	.456	.043*
SIMU_U	**SIMU_A**	Simulation	Tool and Technique	.375	.103
CFT_U	**CFT_A**	Cross-Functional Teams	People	.358	.122
TMDEV_U	TMDEV_A	Team Development	People	.303	.195
FRMTB_U	**FRMTBR_A**	Formal Team Briefings	Process	.167	.481
COLOC_U	**COLOC_A**	Co-Location	People	.113	.636

Bold indicates statistical significance at p≤0.05 or p≤0.01 levels when testing the difference between the mean and the mid-point (3) of the survey scale. *Indicates those practices where the use and effectiveness result in statistically significant correlations at p≤0.05 level and ** indicate the same at p≤0.01 level.

Table 6.18 shows that for the entire sample of 20 projects, only four practices were not found to be statistically significant practices in terms of both frequency of use and effectiveness – i.e., where the means for both use and effectiveness were not both significantly greater than the mid-point (3) of the survey scale. These practices include team development and rewards and recognition (people practice); customer/supplier integration, organizational redesign, formal procedures (process practice); computer-aided manufacturing (tool and technique); and QFD (formal method).

The practices that were found to be statistically significant in terms of frequency of use but not in terms of effectiveness include team development (people practice), formal procedures (process practice) and QFD (formal method).

Based on Spearman's Rho, the correlation coefficient, the top three variables that NPD managers were most likely to score similarly for both use and effectiveness in reducing Time-to-Market include design of experiments (formal method), formal procedures (process) and computer-aided manufacturing (tool and technique).

The non-statistically significant coefficients suggest that there may be a gap between the use of a given practice and its effectiveness in reducing Time-to-Market. These practices include: cross-functional teams (people), co-location (people), formal team briefings (process), simulation (formal method) and team development (people).

6.3.1 – Use versus Effectiveness for Incremental and Radical Innovation

a) Results for Incremental Innovation

Table 6.19, below, provides an account of the significant practices that respondents identified as having been used during the NPD process as well as having reduced Time-to-Market, based on the 14 incremental innovation projects. Table 6.19

also provides the results for Spearman's Rho and those correlations between frequently used practices and effective practices that are statistically significant. The non-statistically significant correlations suggest a gap between the rating for the use of a particular practice and its effectiveness in reducing Time-to-Market.

Table 6.19 – Frequently Used Practices versus Effective Practices: Incremental

Frequently Used Practices (Q7)	Effective Practices (Q11)	Name of Practice	Practice Grouping	Spearman Rho Correlation Coefficient	Sig. (two-tailed)
FRMPR_U	FRMPR_A	Formal Procedures	Process	.980	.001**
CSINT_A	CSINT_A	Customer/Supplier Integration	Process	.973	.005**
QFD_A	QFD_A	Quality Function Deployment	Formal Method	.746	.088*
FMEA_A	FMEA_A	Failure Modes and Effects Analysis	Formal Method	.738	.094*
ORGRE_A	**ORGRE_A**	Organizational Redesign	Process	.612	.196
COMPU_U	COMPU_A	Computers/Networks	Tool and Technique	.609	.199
DOE_A	DOE_A	Design of Experiments	Formal Method	.572	.235
DFM_U	DFM_A	Design for Manufacturing	Formal Method	.559	.327
CFT_U	**CFT_A**	Cross-Functional Teams	People	.556	.252
CAD_U	CAD_A	Computer-aided design	Tool and Technique	.539	.269
TMLEA_U	TMLEA_A	Team Leadership	People	.456	.363
PM_U	**PM_A**	Project Management	Process	.447	.374
CAM_A	CAM_A	Computer-aided manufacturing	Tool and Technique	.435	.388
REWRD_A	**REWRD_A**	Rewards and Recognition	People	.433	.391
COLOC_U	COLOC_A	Co-Location	People	.320	.537
SIMU_U	SIMU_A	Simulation	Tool and Technique	.274	.599
TMDEV_A	TMDEV_A	Team Development	People	.000	1.000
FRMTB_U	FRMTB_A	Formal Team Briefings	Process	-1.000	.000**

Bold indicates statistical significance at p≤0.05 or p≤0.01 levels when testing the difference between the mean and the mid-point (3) of the survey scale. *Indicates those practices where the use and effectiveness result in statistically significant correlations at p≤0.05 level and ** indicate the same at p≤0.01 level.

When examining if the means were significantly greater than the mid-point (3) of the five-point survey scale for incremental innovation, only four of the seventeen practices were found to be statistically significant in reducing Time-to-Market at either the p≤0.01 or p≤0.05 levels. These practices include two people practices (CFT and rewards and recognition) and two process practices (project management and organizational redesign). There were ten practices, on the other hand, found to be statistically significant in terms of frequency of use.

Only two practices, CFT (people practice) and project management (process practice) were found to be both statistically significant in terms of frequency of use and effective in reducing Time-to-Market – i.e., that their means were significantly greater than the mid-point (3) of the survey scale. Those practices that were found to be frequently used but not effective in reducing Time-to-Market include co-location and team leadership (people practices); formal procedures and formal team briefings (process practices); computers/networks, CAD, simulation (tools and techniques); and DFM (formal method). The two practices found to be significantly effective but not significant in terms of frequency of use were organizational redesign (process practice) and rewards and recognition (people practice).

Examining Spearman's Rho and the statistical correlations between the use of practices and their effectiveness in reducing Time-to-Market, the top three variables that NPD managers were most likely to score similarly for both use and effectiveness in reducing Time-to-Market include formal NPD procedures (process practice), customer/supplier integration (process practice) and QFD (formal method). The non-statistically significant coefficients suggest that there may be a gap between the use of the practice and its effectiveness in reducing Time-to-Market. These practices include: CAD, CAM, cross-functional teams, co-location, computers/networks, DFM, DOE, organizational redesign, project management, rewards and recognition, simulation, team development and team leadership.

b) Results for Radical Innovation

Table 6.20, below, provides an account of those significant practices that respondents identified as having been used during the NPD process as well as having reduced Time-to-Market, for radical innovation. Table 6.20 also provides the results for Spearman's Rho and those correlations between frequently used practices and effective practices that are statistically significant. The non-statistically significant correlations suggest a gap between the rating for the use of a particular practice and its effectiveness in reducing Time-to-Market.

Table 6.20 – Frequently Used Practices versus Effective Practices: Radical

Frequently Used Practices (Q7)	Effective Practices (Q11)	Name of Practice	Practice Grouping	Spearman Rho Correlation Coefficient	Sig. (two-tailed)
DOE_U	DOE_A	Design of Experiments	Formal Method	.821	.000**
CAD_U	CAD_A	Computer-aided design	Tool and Technique	.757	.002**
CAM_U	CAM_A	Computer-aided manufacturing	Tool and Technique	.708	.005**
PM_U	**PM_A**	Project Management	Process	.633	.015**
QFD_U	QFD_A	Quality Function Deployment	Formal Method	.622	.023*
ORGRE_U	ORGRE_A	Organizational Redesign	Process	.620	.018**
FRMPR_U	FRMPR_A	Formal Procedures	Process	.578	.030*
FMEA_U	FMEA_A	Failure Modes and Effects Analysis	Formal Method	.560	.046*
DFM_U	**DFM_A**	Design for Manufacturing	Formal Method	.528	.064*
COMPU_U	COMPU_A	Computers/Networks	Tool and Technique	.477	.847
FRMTB_U	**FRMTB_A**	Formal Team Briefings	Process	.454	.103
TMLEA_U	**TMLEA_A**	Team Leadership	People	.357	.230
REWRD_U	REWRD_A	Rewards and Recognition	People	.356	.211
SIMU_U	**SIMU_A**	Simulation	Tool and Technique	.345	.227
TMDEV_U	TMDEV_A	Team Development	People	.336	.241
CFT_U	CFT_A	Cross-Functional Teams	People	.270	.350
CSINT_U	CSINT_A	Customer/Supplier Integration	Process	.209	.474
COLOC_U	COLOC_A	Co-Location	People	-.018	.951

Bold indicates statistical significance at $p \leq 0.05$ or $p \leq 0.01$ levels when testing the difference between the mean and the mid-point (3) of the survey scale. *Indicates those practices where the use and effectiveness result in statistically significant correlations at $p \leq 0.05$ level and ** indicate the same at $p \leq 0.01$ level.

For radical innovation only five out of the seventeen practices were found to be statistically significant in reducing Time-to-Market at either the $p \leq 0.01$ or $p \leq 0.05$ levels –

i.e., where the mean was significantly greater than the mid-point (3) of the five-point survey scale. These practices include one people practice (team leadership), two process practices (project management and formal team briefings), and two formal methods (DFM and simulation). There were ten practices, on the other hand, found to be significant in terms of frequency of use, where the means were significantly greater than the mid-point as indicated in bold.

There were four practices that were found to be frequently used but that were not significant in reducing Time-to-Market according to respondents. These practices include co-location, CFT (people practices); computers/networks and CAD (tools and techniques).

Examining Spearman's Rho and the statistical correlations between the use of practices and their effectiveness in reducing Time-to-Market, the top three variables that NPD managers were most likely to score similarly for both use and effectiveness in reducing Time-to-Market include DOE (formal method), CAD (tool and technique) and CAM (tool and techniques). The non-statistically significant coefficients suggest that there may be a gap between the use of the practice and its effectiveness in reducing Time-to-Market. These practices include: cross-functional teams, co-location, formal team briefings, computers/networks, customer/supplier integration, rewards and recognition, simulation, team development and team leadership.

Chapter 7 – Discussion

7.1 – Significant Findings

Overall, the survey results show that there are not many differences regarding the use of CE practices for incremental and radical innovation. These differences are attributed to their effectiveness in reducing NPD cycle time, rather than with their actual use. There are more CE practices that are effective in reducing Time-to-Market for radical innovation than incremental innovation. While the individual relationships between the CE practices and Concept-to-Customer Time and Development Time could not be examined due to a lack of data, NPD managers did indicate that these two measures of time were reduced as a result of having used CE practices, regardless of the type of innovation (i.e., radical or incremental). Development Time was the most highly reduced time on average for the entire sample.

The results suggest that while NPD managers are using CE practices, they do not perceive all of these practices as being effective in reducing NPD cycle time. Perhaps the practices help achieve other performance goals or perhaps NPD managers are simply not able to change their use of practices. This is particularly true for radical innovation. The practices play a less significant role in reducing time at the new product strategy stage (where Concept-to-Customer Time begins), versus the detailed design, prototype development, pre-production and production stages (which are all included in Development Time).

The findings show that all of the CE practices listed for respondents are significantly important practices. These practices, in order of importance, include: CFT, DFM, project management, QFD, simulation, team development, computers/networks, CAD, DOE, formal procedures, co-location, formal team briefings, CAM, team leadership, rewards and recognition, FMEA, organizational redesign, and customer/supplier integration.

While NPD managers recognize the importance of CE practices for NPD, they do not necessarily use them all. Twelve of the eighteen practices were found to be significant practices in terms of frequency of use (i.e., used sometimes, often or always) – i.e., where the means were significantly greater than the mid-point (3) of the survey scale. These practices, in order of frequency of use, include project management, computers/ networks, co-location, CFT, CAD, DFM, simulation, team leadership, formal team briefings, formal procedures, QFD, and team development. For incremental versus radical innovation, the list of frequently used practices in order of significance differ.

The findings show that the list of significant practices decreases with regards to their effectiveness in reducing NPD cycle time, specifically, Time-to-Market. Only half of the practices are significantly effective in reducing NPD cycle time. From most effective to least effective, the practices include: project management, CFT, DFM, CAD, simulation, computers/networks, team leadership, co-location, and formal team briefings.

7.2 – Explanation of Research Questions and Hypotheses

7.2.1 – Frequently Used CE Practices

The first research question examines the frequency of use of CE practices in Canadian Electronic Parts and Components Manufacturing firms. NPD managers were asked to identify the extent to which they used CE practices in the overall development of new or significantly improved products that were introduced into the market in the last six months. The section on effectiveness of NPD practices provides NPD managers with information that might help them address if the practices are applicable to them. If they are focused on speed-to-market, they might want to implement those practices that are effective in reducing time which their fellow industry members are using frequently.

Of the eighteen practices that were found to be important practices for CE, twelve were found to be significant in terms of frequency of use. These findings are valuable as they contribute to an area of research which is lacking support. A review of the literature failed to find much support for extent of use of CE practices. Although many researchers study their importance and their effectiveness in improving NPD performance, very few of them explore the extent to which they are used in CE (Portioli-Staudacher *et al.*, 2003; Maylor, 1997; Karagozoglu and Brown, 1993; Whildschut and Wiggers, 1993; and Winner, 1988). Therefore, one of the major benefits of this research is the additional information it provides NPD managers on use of practices. Moreover, it allows NPD managers to benchmark their use of the practices against the use by other NPD managers.

According to Portioli-Staudacher *et al.* (2003) "CE is an integrated approach which consists of [a combination of] different tools, techniques, policies, etc. therefore the measures of such implementation is not straightforward." This could explain why there is so little data in this area. Another reason has to do with the problems companies face in implementing CE. According to Pawar and Driva (1996), CE implementation is not without its problems. Boyle (2003) summarized some of the impediments to the diffusion of integrated product development and innovation that are relevant to CE. These factors consists of for example, top management commitment, personal characteristics, organizations issues, etc. Implementing CE requires careful consideration of these factors, particularly culture, education and employee involvement, to ensure smooth usage or implementation.

It is also interesting to note that the work of Portioli-Staudacher *et al.* (2003), Maylor (1997), Trygg (1993), and Whildschut and Wiggers (1993) are based on data from foreign companies (Japanese, UK, Swedish, Italian and Belgium), leaving only one study found on the use of practices in North American companies. Hence this study adds to the North American experience.

The following elaboration on the findings of this research also presents complementary findings collected from the literature. Table 6.2, in chapter 6, recaps the ranking of the frequently used practices found through the data analysis. Three of the four tools and techniques were found to be significant in terms of frequency of use; computers/networks, CAD and simulation. Three of the five process practices were found to be significant in terms of frequency of use; project management, formal team briefings and formal NPD procedures. Two of the four formal methods were found to be significant in terms of frequency of use; DFM and QFD. The findings suggest that people practices with the exception of rewards and recognition are among the most significant practices in terms of frequency of use. This has important implications for companies that are trying to perfect their technologies and platforms, and ensure that they are staying at the cutting-edge. The fact that people practices are so heavily used (as suggested by the data) implies a great deal of importance of people in the NPD process. Therefore, NPD managers must balance the need to implement and use cutting-edge technology with the use of people as opposed to automation. For researchers, the implications of such findings mean that studying relationships between new technologies and people will be relevant to industry experiences.

According to the findings, NPD managers are most likely to use people and tools and techniques without spending too much of their efforts on the bureaucracies or procedures that define how activities should be undertaken. They use the organizational processes and business practices as facilitation techniques. Of course, this depends on the discretion of NPD managers in using process practices and on the style of organization. Nevertheless, the rankings of the practices indicate that there is some balance in the extent to which NPD managers use different types of practices. While people practices (team development, team leadership, CFT, and co-location) are heavily relied upon, NPD managers focus on a blend of tools and techniques (computers/networks, CAD, and simulation), process practices (project management, formal NPD procedures, and formal team briefings), and even formal methods (design-for-manufacture, QFD).

As indicated above and in the literature review, project management was the most frequently used practice by the NPD managers (Maylor, 1997; Barclay and Dann, 2000; and Ainscough and Yazdani, 2000). Portioli-Staudacher *et al.* (2003), however, found the contrary to be true for project management. The review of literature failed to find further support for the frequency of use of project management, however, similar to the studies of Ainscough and Yazdani (2000) and Barclay and Dann (2000) there are a large number of studies regarding the benefits and effectiveness of project management. There were no studies found suggesting that NPD projects do not involve frequent use of project management. This is a valuable consensus for NPD managers to note as it implies that CE cannot be fulfilled without this practice.

The second most frequently used practice is computers/networks. Computers/networks help with the concurrency of design by providing team members with common databases to communicate and share information (Cleetus and Reddy, 1992). Despite the findings of Barclay and Dann (2000) that suggest that companies place less importance/emphasis on computers/networks as integrating elements, Brynjolfsson and Hitt (2000) state that "the majority of modern industries are being significantly affected by computerization". Computers/networks have transformed the way things are done at all levels of society. The Conference Board of Canada's (2003) connectedness research and data produced by Statistics Canada on the use of information and communication technologies in Canada show that the use of such technologies has significantly increased. The findings by Portioli-Staudacher *et al.* (2003) support the findings of this research regarding the use of computer/networks. There are no recent studies found that contradict the findings of this research regarding this practice. This consensus suggests that computers/networks are fundamental for CE. The importance of this finding is important for NPD managers to note. As already seen with the prevalence of wireless computer technologies, the way in which computers and networks are used are becoming increasingly sophisticated (e.g., use of computers for voice over internet protocol, e-commerce). Such usage has been proven to provide users with added benefits, such as cost-savings or speed-to-market, which contribute to the competitiveness of the organization.

Moreover, computers/networks provide the necessary infrastructure for other frequently used CE practices such as computer-aided systems, simulation, and DFM. The findings of this research suggest that these practices are frequently used practices for NPD managers. Similarly, the findings of other researchers support the frequent use of computer-aided tools. The consensus of the studies regarding the frequent use of CAD implies that it is another critical component to CE (Kessler and Chakrabarti, 1999; Karagozoglu and Brown, 1993; Cordero, 1991; and Winner *et al.*, 1988). Using this tool often require staff that is skilled in using it and financial resources to ensure that the technology remains current and functional.

Another frequently used practice is DFM. The findings of this research support the findings of other researchers studying the use of DFM (Winner *et al.*, 1988; and Kessler and Chakrabarti, 1999) as well as contradict other researchers' findings (Portioli-Staudacher *et al.*, 2003; and Abdalla and Knight, 1997). Portioli-Staudacher *et al.* (2003), however, explain that the infrequent use of DFM in the companies they studied could be due to a lack of understanding of the tool. On the other hand, the tool might not be applicable to all types of organizations and projects. NPD managers should recognize that this practice might not be applicable to their situation. By determining the pros and cons for their situation, they will have a better opportunity to identify how the practice should be used if it is appropriate. NPD managers should also ask themselves what impact DFM will have on the NPD process and if this impact is worth the costs. Given the contradictory results, researchers might want to do further study on the use of this practice; understanding the reasons for use or no use and what types of companies use it.

With regards to simulation, the review of literature failed to find any data on the frequency of use of this practice. This research found simulation to be a statistically significant practice in terms of frequency of use. The benefit of this research is that it provides NPD managers with some preliminary information regarding its use.

As indicated earlier the findings also suggest a number of frequently used people practices, such as co-location and CFT, that NPD managers rely on simultaneously with computers and computer integration systems. Such findings confirm the dependency of NPD on people. People play a very important role in generating new ideas and transforming them into new or significantly improved products or processes. The practices that enable people to fulfill these activities are also frequently used by NPD managers as suggested by the findings. These practices include team-oriented practices (such as team development and team leadership).

The literature review provided support from several studies that CFT is among the most frequently used CE practices (Karagozoglu and Brown, 1993; Portioli-Staudacher *et al.*, 2003; Allen, 1997; Maylor, 1997; and Winner *et al.*, 1988).

Alternatively, while Henke *et al.*'s (1993) findings suggest that "there is a very pronounced tendency toward the overuse of teams", their findings also suggest a declining trend in the use of CFT. They cite as examples, Honda's reasons for disengaging in the use of CFT. These include: "taking too much time," or "frequently coming up with dull ideas rather than more daring and creative ones". Despite this declining trend, Henke *et al.* (1993) do not necessarily recommend abandoning the use of teams rather they recommend continuously refining and upgrading the team's skills and interaction processes (team development).

As indicated by the review of literature and the findings of this research, there is strong support for the use of CFT in CE. This is not an unexpected finding. The importance of this finding, however, is that it confirms that much of the literature which has been based on foreign companies can be complemented with research on the use of CFT in North American companies. Another reason why this finding is important is the confirmation it provides those companies that are still operating within silos. While frequent use does not suggest increased effectiveness it does show that companies are trying to breakdown barriers and increase internal communications by increasing the amount of collaboration that occurs within the company. CFT is one way of enticing collaboration and partnerships among employees. In the future, researchers might want to assess whether such collaboration can lead to an increase of partnerships forming externally with members of other organizations as well (e.g., suppliers, customers, competitors, professional associations).

As suggested by the findings of this research, the majority of NPD managers surveyed also understand the importance of developing their teams. This is implied through their frequent use of team development activities. This finding is supported by the research of Abdalla (1999) and Barclay and Dann (2000). In terms of team leadership and formal team briefings, the review of literature failed to find any further support for the extent to which team leadership or development are used for CE. This finding suggests that akin to individual teams require proper management and training in order to develop their skills and capabilities.

Complementary to the frequent use of CFT, is the frequent use of co-location based on the findings of this research. Co-location is used to foster collaboration and trust which in turn helps facilitate more effective and higher performing teams (King and Majchrzak, 1996; Barclay and Dann, 2000). The review of literature failed to find any support for the actual use of co-location in NPD projects. This finding suggests that companies are using co-location because they believe in the benefits it provides. On the other hand, they might also be using it because of it makes business sense to do so. If they only have one facility or plant then co-location would be the obvious decision. In the case where they have multiple plants, co-location of team members might have been the obvious solution if plants were divided by product lines or types of projects. While there are many inputs that go into the designing of a company's layout, it is interesting to see how many companies include co-location in those decisions.

This is especially important considering the role that computers/networks play. With the increased use of e-mail, VOIP, teleconferencing, etc., there are fewer reasons for the need for co-location and more possibilities to replace it with virtual co-location. Researchers might want to track over time the changes in the use of co-location and reasons for any changes. Researchers might also want to determine if companies co-locate certain activities in particular regions in order to take advantages of the workforce, cluster of other firms, tax benefits that region might provide.

It is interesting to note that the most frequently used practices are also those with the most consistent results throughout the literature. These include project management (process), computers/networks (tool and technique), co-location (people) and CFT (people). In the literature they might belong to different labels but all share one common contribution – that is their ability to provide better coordination and communication for workers. According to Karagozoglu and Brown (1994) each of these practices plays an important role in facilitating the overlapping of activities and the integration of various functional departments.

This combination suggests that NPD managers are demanding that a greater sophistication of skills, knowledge and experience be brought to the fulfillment of NPD activities. These NPD managers are trying to find ways to break down silos and increase the amount of interdisciplinary communication that takes place. Finally, frequent use of these practices also suggests that NPD managers look for ways to do things "smarter, not harder" through better planning, automation and synergies created from interdisciplinary teams.

At the same time, combining these different practices can also present different tensions for the NPD managers. More frequent use of teams can lead to greater conflicts between NPD managers and require stronger leadership to assist the team in finding accepted methods and words (e.g., jargon) for sharing ideas. Computers and networks will need to be managed as they require skills and knowledge to operate, back-up plans in case of breakdowns, etc. Co-location can lead to increased re-location of team members or facility requirements which can result in additional expenses such as accommodation and re-location costs or infrastructure investments.

Like CAD and DFM, QFD is another frequently used practice for the NPD managers surveyed. The research of Abdalla (1999) and Winner et al. (1988) support these findings. Studies by Portioli-Staudacher et al. (2003) on Italian and Belgian companies and Maylor (1997) on UK companies, contradict the findings of this research. Similar to DFM there are contradicting findings regarding the use of QFD. It appears that more research is needed in the area of formal methods and their frequency of use. Not all NPD managers agree in the extent to which these practices should be used.

The last frequently used practice found in this research is formal NPD procedures. Many other researchers have also studied the use of this practice (Griffin, 1997; Hull *et al.*, 1996; Liker *et al.*, 1999; Lynn *et al.*, 1999; Kusunoki *et al.*, 1998; Pinto et al. 1993; Rusinko, 1999; and Tatikonda and Rosenthal, 2000b) however, depending on how they define this practice their results differ. For example, Rusinko (1999) looks at NPD procedures in the form of guidelines for manufacturing while Liker *et al.* (1999) look at formalization of work practices. Rusinko (1999) findings suggest that the practice does contribute to time reduction while the same was not found by Liker *et al.* (1999). The findings of this research contribute to this area of study. It identifies a practice which has not been explained in great detail by the literature but that NPD managers rank among their frequently used practices, albeit not highly. Nevertheless, as use does vary, NPD managers will need to identify if the practice is applicable to them.

Other practices that NPD managers use for reducing NPD cycle, according to the additional comments they provided in the survey, include:

- "Better and more realistic product definition"
- "Earlier involvement of manufacturing"
- "Better trained people to take the product from development into manufacturing"
- "Project leader or lead engineer is critical. He/she must be very strong at multi-disciplines and can communicate well with functionally different team members"
- "Strong leadership who is comfortable providing the right attitude to change and is in tune with the target market"
- "Design-for-six-sigma is important"
- "Parallel paths for technical risks are critical"
- "It is very important to manage the critical path of each development program and to reduce the technical risks of each development branch"
- "Always run parallel project paths when the technical risks are poorly understood"

- "An incremental increase to the product development costs is negligible if you're not first to market. By contrast, if you don't spend the extra money upfront and you're late to market you may never recover your investment costs"
- "Some structure to balance requirement changes, the market impact and the cost of the change"
- "Researching the material capability to comply to specification requirements required by the product"
- "A culture that promotes recycling and reuse"

It is interesting to note that if these practices were grouped under the four categories of practices, people, process, tools and techniques and formal methods none of them would fit under the tools and techniques category. The practices are biased towards people practices and formal methods. This could be because the people and process practices list for them did not include the ones they most highly regarded. Another interpretation is that NPD managers are continuously searching for the right people practices and formal methods while technologies remain stable and hence become an issue less in the minds or concerns of NPD managers.

This emphasis on people and formal methods is not a surprising one. Technology, regardless of how great it is, requires people and best practices to operate. Until all processes and activities are replaced by artificial intelligence people and the way they operate will need to remain on the minds of management.

In addition to discussing the frequently used practices, it is interesting to point out those practices that were not found to be frequently used by the NPD managers surveyed. The non-significant practices include customer/supplier integration (process practice), CAM (tool or technique), FMEA (formal method), rewards and recognition (people practice), and organizational redesign (process practice). These practices were also among the six least important practices.

As in all facets of business, NPD managers make choices when implementing practices. They decide on the level of appropriateness based on the type of product to be developed, conditions (e.g., time allotted), their gut feel, experience, etc. (Poolton and Barclay, 2000; Portioli-Staudacher et al., 2003). As a result not all companies use similar practices. Despite the variance, however, certain findings of this research are highly unexpected. The most notable is with customer/supplier integration.

According to the literature customer/supplier integration is frequently used in CE (Portioli-Staudacher *et al.*, 2003; Maylor, 1997; and Karagozoglu and Brown, 1993). The literature also explains the importance this practice plays in increasing coordination by integrating the ideas, needs or expectations of customers and suppliers early on in the development process (Rogatz *et al.*, 1997; Liker *et al.*, 1999; and Kessler and Chakrabarti, 1999). This finding is interesting as The Conference Board of Canada (2003) research indicates that more innovative firms are more likely to integrate customers in the NPD process. NPD managers and researchers should consider the benefits this practice provides and ways of increasing customer/supplier involvement.

Among the technologies, tools and techniques, the findings from this research suggest that CAM unlike CAD is not a frequently used practice. The findings of Winner *et al.* (1988) suggest that CAM, like CAD is a frequently used practice. The findings of this research are surprising. What makes CAM so different from CAD? While it could be related to the size (no. of employees) of the companies, the findings from this research did not show that size played a role when it came to the use of CAM. In fact the majority of more than half of the small and medium (employ less than 500 employees) companies indicated that they used it frequently while large companies were more likely to indicate that it was moderately used.

Use of CAM could also be related to the stage of the NPD process. Karagozoglu and Brown (1993) found that computer-aided tools were often used in only one phase of the NPD process. Hauser and Clausing (1998) found that part of the reason for this is because of the lack of experience regarding their use in downstream stages. Another interpretation could be that firms and NPD projects place more emphasis on the tools required in the design stages and less so in the manufacturing or production stages. This was certainly another unexpected finding since it is unexpected that this practice would be much different from CAM. Researchers might want to look more closely as to why this practice is not frequently used. It could be that it does not need to be used frequently in order to be effective.

FMEA was another practice that was not found to be frequently used by the NPD managers surveyed. The findings by Portioli-Staudacher (2003) based on Italian and Belgian companies both support and contradict this finding. Maylor's (1997) findings indicate that UK firms are similar to the Belgian ones, in that a majority of them are likely to use the practice often. The literature review failed to find any other findings that help to clarify the use of FMEA in the CE environment. The contradictions in research findings suggest that there is a still a lack of understanding around the use of this practice. Researchers might want to look more carefully into the reasons for such discrepancy. NPD managers will need to acknowledge that this practice might be more applicable on a case by case situation and perhaps not applicable to all.

There is research that supports the use of rewards and recognition in meeting NPD cycle time goals. Hull *et al.* (1996) found that team rewards and recognition can impact NPD performance. Susman and Ray (1999) also found that project based rewards impact project outcomes, such as time. The results of this research suggest that NPD managers are not using rewards and recognition frequently. This means that they could be loosing out on potential opportunities for improving the delivery of NPD projects.

Regarding the results obtained for the use of organizational redesign the review of literature failed to find any data on the use of this practice.

Of course, these studies had to have been based on firms using this practice, which implies that firms are using it, but it is unclear as to the extent of use. The findings of this research help provide more information to that regard. The data suggests that NPD managers are either not given the resources they need to reward and recognize staff, lack vision in doing so or fail to fulfill the step that comes before rewarding and recognizing, which is evaluating performance. Researchers might want to look into the reasons for the lack of rewards and recognition.

7.2.1.1 – Practices used frequently together

Another approach for examining the frequency of use of practices is by studying their relationships with other practices. The findings of this research show that certain practices are likely to be used in the presence of other practices, while others are not correlated by use. The CE practices that are frequently used when another practice is being used include:

- Computers/Networks & CAD;
- CAD & Simulation;
- Project management & Team leadership;
- Project management & Formal Team Briefings;
- Project management & QFD; and
- QFD & Team development.

The first two correlations are intuitive. Computers are an essential tool for CAD systems and simulation is conducted through CAD systems. The third, fourth and fifth correlations with project management and team leadership require some interpretation.

In the case of the correlations between project management and the two team-related practices (team leadership and formal team briefings), research shows that project management environments are usually highly dependent on teams. Leadership is an essential characteristic of CFT. Higher performing teams are given greater autonomy, more decentralized decision-making and less interference from functional managers. Project management focuses on increasing the coordination between NPD stages as well as between team members. Formal team briefings help increase the communication and information sharing of the project requirements with all team members. They are complementary since project management keeps track of planning and coordinating activities and formal team briefings ensure all members are aware of goals and activities set forth in the project. One way of ensuring the continued use of these practices together is by formally integrating team-related activities into the project's many activities.

With regards to the correlation between project management and QFD, both of these practices emphasize specifying requirements. Project management includes all the requirements of the project as a whole and QFD focuses on specifying the requirements of the product design based on the customer desires. This finding suggests that QFD can be seen as a more specialized sub-component of project management. This is an important finding as project management is one of the most frequently used practices in CE. Tools, processes and methods can help a manager or team leader manage the project much more smoothly. The findings suggest that another "tool in the toolbox" is QFD.

Another interesting aspect of the findings pertaining to the use of QFD with project management is the use of customer/supplier integration. While the results of this research do not suggest that NPD managers are using customer/supplier integration frequently, they are however focused on integrating customer requirements through the QFD. This finding suggests that NPD managers are likely to use QFD as a substitute for the practice of integrating customers/suppliers. NPD managers should take the time to consider which practices are most appropriate and consider substitute practices.

The last correlation found is between QFD and team development. This relationship was unexpected, as these two practices seem unalike. The findings, however, suggest they share actually similarities in that they are both process-enabling practices. While QFD enables the team to have a better understanding of product requirements, team development enables the team to have a better understanding of the relationships, dynamics and requirements of the team. For an organization focused on facilitating processes these two practices would apply. These findings suggest that when activities occur in parallel or concurrently, as they do in CE, companies put additional efforts into avoiding confusion or ambiguity by implementing practices that help make tasks clearer and more defined.

In addition to discussing the significant correlations, it is also interesting to point out the non-significant correlations, in particular those that were unexpected. For example, it is interesting to see that there is no significant relationship between the frequency of use of any of the tools/techniques and the people practices. Based on the results of several researchers (Berndt, Morrison and Rosenblum, 1992; Berman, Bound and Griliches, 1994; Autor, Katz and Krueger, 1998), the relationship between people and computers and computer-aided tools has been proven. Brynjolfsson and Hitt (2000) posit that such findings are also consistent with their analysis indicating a strong relationship between the increase in use of computers and computer-aided tools and the greater need for human capital. The findings of this research, however, suggest that NPD managers might be missing the opportunities that come from combining tools/techniques and people practices together or even from substituting one with the other. While these tools (e.g., CAD) are not the types of tools that replace everyday low-skilled labour, they could be used to substitute certain activities (e.g., complex calculations and computations). There is no pattern in the use of these two types of practices as they relate to one another, as indicated by the NPD managers. Researchers might want to look at why such opportunities might be missed and ways to help NPD managers put both into complementary use.

Another two relationships that were not found to be significantly correlated and that were unexpected were between team development and CFT, and team leadership and CFT. Intuitively, one would think that if companies are using CFT frequently they should also be focused on developing these teams and ensuring that they have the appropriate level of control and empowerment in the organization. According to Henke *et al.* (1993) the more upper management takes away authority from the team the dissipated the inherent benefits and value of the group concept are likely to become. These findings suggest that NPD managers that are using CFT are not putting the same efforts into developing or empowering these teams. This could be a result of the fact that these practices are based on the type of innovation being developed. It could also mean that team leadership and development have occurred sometime in the past and that are no longer in the mind of NPD managers. The implications of not properly developing or empowering a team can lead to a non-functional group of people and negative results. NPD managers, dependent on teams, should ensure that the teams have the resources and power needed to perform.

Co-location is another practice that was unexpectedly not correlated with the use of CFT. According to Takeuchi and Nonaka (1986) and Susman and Dean (1992), co-location is a way of bringing team members together and creating stronger bonds among team members. This finding is extremely surprising since both of these practices were among the most frequently used practices for CE. Researchers might want to take another look at understanding the use of co-location when using CFT.

Arguably, the most surprising finding was that there was no significant relationship found between the use of CFT and customer/supplier integration. While the literature says that customer/supplier integration is a key entity of CFT (Kessler and Chakrabarti, 1999), the results of this finding suggest that NPD managers and NPD managers often leave them out of the group. This could be simply that the NPD managers are not aware of the benefits such members provide to the team or that they have not yet identified their customers and suppliers. There is significant value in integrating customers and suppliers into the CFT. The Conference Board of Canada (2004) research has found that organizations that generate a higher percentage of their sales from radical or incremental innovation are those that integrate their customers and suppliers into the creation, diffusion and transformation of ideas for those products. As explained earlier, other researchers have also found that there are many benefits to integrating customers and suppliers in the use of CFT. This is a very important finding as it indicates that companies are not realising their full potential when developing new or significantly improved products. By failing to integrate customer and supplier into the NPD process they might also be at the risk of developing products that the market will not want. This will make it harder for them to commercialize their products – a case which has already been proven in Canada.

7.2.1.2 – Use of Practices by Type of Innovation

This study contributes new findings to the body of literature on CE practices and NPD cycle time by introducing type of innovation (i.e., incremental or radical) as a moderating variable. The model of this research hypothesized that the type of innovation moderates the relationship between CE practices and the effectiveness of the practices in reducing NPD cycle time; Time-to-Market, Concept-to-Customer Time and Development Time.

As explained in previous chapters, the type of innovation in this study is defined as incremental and radical innovation. Before comparing the differences between these two types of innovation, the frequency of use and importance of the practices for each type were examined individually. Of the eighteen practices examined in this study, ten of them were found to be significant in terms of frequency of use for incremental innovation and nine of them were found to be significantly effective for radical innovation. The practices for both types of innovation were also found to be significantly important practices for reducing NPD cycle time, with the exception of team leadership in the case of radical innovation. This practice was found to be used frequently but was not found to be significantly important for radical innovation. This means that although NPD managers are using team leadership they are not convinced that team leadership is an important practice for reducing NPD cycle time. In essence there is gap between the perceived importance of the practice and the extent to which it is used.

When comparing the frequently used practices for incremental and radical innovation, as shown in Table 6.8, the results reveal that there is only one practice that was statistically significant in terms of use for only one of the two types of innovation. This practice is formal NPD procedures (significant for incremental innovation not radical). Rewards and recognition, team development, customer/supplier integration, organization redesign, CAM, design of experiments and QFD were not significant for either types of innovation.

One interpretation has to do with the possibility that not all NPD managers differentiate between incremental and radical innovation when developing these types of innovation. Another way of interpreting or understanding the differences in the use of these practices for incremental and radical innovation has to do with the nature of the type of innovation.

For instance, NPD managers developing radically new products do not use the same level of formal NPD procedures as used in incremental innovation. Radical innovation projects may be relying on formal procedures regarding how to develop new products in general, but they would not have documented procedures for a specific product since they would involve developing a completely new product which the organization has no previous experience. According to Kessler and Chakrabarti (1999) radical innovation projects do not include the same precedents as incremental innovation projects and entail less clarity around the appropriate activities and tasks. Incremental innovation projects may have access to formal NPD procedures regarding the specific product that is being improved. This is true since incremental innovation involves building upon pre-existing technologies and/or capabilities that the organization has already developed in previous product development projects. Nevertheless, intuitively it could be thought that formal NPD procedures could be more beneficial for radical innovation projects in helping to guide ideas through the NPD process.

Despite the similarities in the types of practices frequently used in incremental and radical innovation projects, the interesting differences come from the extent of use of the practices for each type of innovation. When examining the differences in the mean scores for frequency of use of the practices in incremental versus radical innovation projects, a statistically significant difference was found for four practices. These include: team leadership (people practice), co-location (people practice), CAD (tool and technique) and simulation (formal method).

Projects focusing on radical innovation were much more likely to use these practices than the incremental projects. The results imply that incremental innovation projects do not require as many practices possibly because they do not entail as many problems. The importance of these findings is that they help NPD managers identify more specifically the practices that other NPD managers are using given the type of innovation developed. This distinction might help them avoid practices that are not necessarily needed and focus on those practices that are heavily used given the type of innovation. Since use of practices is not always directly related to effectiveness, the following section identifies those practices that are effective in reducing NPD cycle time. Nevertheless, the larger number of companies using a certain practice might suggest that the practice has proven to be effective for them and thus can be used as a proxy for supportive practices.

The findings for this research show that simulation and CAD are practices commonly used with one another. For radical innovation especially, CAD and simulation allow team members to see what the product is going to look like in the final stages of development and perform possible tests on it to determine its robustness within the external environment. These two tools help eliminate some of the ambiguity regarding the success of product. It provides a view of future points in the project, which are much more unknown in radical innovation projects.

For team leadership it was expected that there would be a difference in the extent to which this practice is used by incremental and radical innovation projects. According to Peters (1987) team leadership is important for radical innovation projects in order to promote projects and take them through bureaucratic snags. In such situations, the team often needs to make unprecedented decisions around how to transform the project into a commercially ready product. If they are being second-guessed by management or not given the room to make the appropriate decisions, this will often de-motivate the team and value of the group concept might more easily become dissipated (Henke *et al.*, 1993). Based on Kessler and Chakrabarti's (1999) findings, the researchers concluded that when the "innovation is highly uncertain and complex, a high degree of project team empowerment is most appropriate". This conclusion is also supported by the work of Damanpour (1991) and Ettlie et al. (1994) support this.

An alternative view, however, might also be interpreted with regards to the use of team leadership for radical innovation versus incremental innovation. In some instances team leadership might be more appropriate for incremental innovation projects. Since incremental projects involve building upon pre-existing knowledge and technologies, there could be less risk involved in giving the team more empowerment in such cases. For radical innovation, more ambiguity is involved and the team faces new challenges when developing the radically new product. These new challenges could distract from corporate objectives and goals. The more ambiguous the project could mean the greater the possibility that the project goes out of control. By giving less empowerment to the team, the organization has more control over chaos or disruptions that might occur.

As for co-location, it is not surprising that this practice is more often used for radical innovation projects than for incremental innovation projects. The literature clearly depicts co-location as being a stronger mechanism for coordination and integration (Zirger and Hartley, 1997; Meyer, 1993). When members are closer to one another, there is room for more face-to-face contact and increased synthesis and transfer of complex information (Keller, 1994). Kessler and Chakrabarti (1999) state that as a result "it provides a better fit with the fuzzy, uncertain nature of radical innovation...". Co-location is less important for incremental innovation as increased communication can in fact lead to greater interruptions and complexity when tasks are more familiar (Kessler and Chakrabarti, 1999; and Perlow, 1996). This is an important finding since it helps NPD managers avoid unnecessary costs around co-location in the case for incremental innovation projects. It helps NPD managers focus on other relevant practices that do make a significant contribute to the development of incremental innovation.

Another practice where there is a difference in extent of use for incremental versus radical innovation projects has to do with customer/supplier integration, albeit this difference is not statistically significant. The very nature of radical innovation projects requires working with breakthrough ideas that have high risk and low uncertainty about market acceptance. The fact that NPD managers of radical innovation projects are more likely to use customer/supplier integration in their projects indicates the importance of gathering as much information from wherever possible to mediate the risks involved with radical innovation. A recent Conference Board study shows that collecting such information is characteristic of more innovative firms. In studying the differences between more and less innovative firms, where level of innovativeness is determined by the percentage of revenue derived from new or significantly improved products, The Conference Board of Canada found that more innovative firms were more likely to integrate their suppliers and customers into their NPD activities (The Conference Board of Canada, 2003). This suggests that by integrating the ideas of the future buyers and partners more success in terms of deliverance of new and significantly improved products could result. In the case of radical innovation, where market success is difficult to determine, additional information can prove to be very useful.

One practice where there were no differences in the extent of use for radical versus incremental innovation was with the use of CFT. There was also very little difference between the two types of innovation in their use of project management and computers/networks. This is not surprising, since the literature suggests that these practices are often used for CE projects regardless of type of innovation (Portioli-

Staudacher *et al.* (2003). This further confirms that while there are certain practices that can be sacrificed certain practices are fundamental to the proper functioning of CE.

Finally, it is interesting to note that the findings for team development suggest that neither radical nor incremental innovation projects are likely to use this practice. This finding was unexpected especially as it relates to radical innovation projects. In radical innovation, the team is dealing with more ambiguity and complexity and the need for multiple areas of expertise is also higher (Bower and Hout, 1988). In addition to this, the distractions of working within a team can become very burdensome. By training the team to work better together and assisting them as they go through the normal team development stages (e.g., norming, storming) they could become more comfortable within their environment and learn to focus more of their attention on the challenges and ambiguity of the project (Henke *et al.*, 1993).

In summary, the practices that seem to distinguish radical from incremental innovation in terms of frequency of use include team leadership, co-location, CAD, simulation, formal team briefings and customer/supplier integration. Team leadership can help NPD managers of radical innovation have more autonomy and decision-making power when it comes to generating completely new ideas for breakthrough products. Co-location can help NPD managers of radical innovation projects increase communication and reduce miscommunication of new activities. CAD and simulation help reduce the risks and costs of experimentation and failure regarding ideas for radical innovation projects. Customer/Supplier integration helps NPD managers of radical innovation mediate the risks of breakthrough ideas by testing the ideas and gathering suggestions from the market beforehand. Formal NPD procedures helps NPD managers of incremental innovation formalize their NPD processes by documenting them and using them as guidelines.

These are very interesting findings as they suggest that while there are not many, the major differences in the use of practices between incremental and radical innovation have to do with the level of frequency rather than type of practices used. The data suggests that NPD managers are much more likely to use CE practices for radical innovation in order to compensate for its complexities.

7.2.2 – Effectiveness of CE Practices in Reducing NPD Cycle Time

The second research question examines the effectiveness of CE practices in reducing NPD cycle time, where cycle time is measured as Time-to-Market, Concept-to-Customer Time or Development Time. Each time measure starts at different stages of the NPD process and ends with the production stage. Time-to-Market measures the entire process starting from market finding, Concept-to-Customer starts at the new product strategy stage and Development Time starts at detailed design and prototype development stage. The significance of measuring time this way and identifying which practices reduce which time measures, allows for a better understanding of the practices used during the different stages of the NPD process.

One of the survey respondents made a comment summarizing the thoughts shared by the other survey respondents regarding time. “Our customers want us to hurry up to get our part of the project done so that they can sit on the product until they actually need it and then go through the hoops to meet their delivery targets.”

The model for this research hypothesized four relationships regarding the effectiveness of each of the four groups of practices on the reduction of time. Each of these four statements was divided into three sub-parts:

a) considered Time-to-Market;
b) considered Concept-to-Customer Time; and
c) considered Development Time.

The results suggest that CE practices have a significant positive effect on Time-to-Market. The findings are consistent with the literature.

In the survey, respondents were asked to identify the extent to which the list of CE practices reduced Time-to-Market. The same type of question, however, was not provided for the other two cycle times. For the other two cycle times, respondents were asked to indicate the extent to which these times were reduced as a result of CE practices. Using correlation tests between the use of practices and reduction of the other two cycle times, did not result in any significant results and thus made it impossible to examine the relationships between each practice and the two other cycle times (i.e., development and Concept-to-Customer Time). Either additional questions focusing on Concept-to-Customer Time and Development Time should have been included or a larger sample size could have sufficed. Using the limited data at hand, meant that the results were highly sensitive to any outliers. Future research could include more precise measures of for capturing the relationships between the other two cycle times and CE practices.

Table 7.1, below, summarises the confirmed hypotheses with regards to reducing Time-to-Market. A negative relation depicts a reduction in Time-to-Market when a particular CE practice is used. A positive relation depicts lack of reduction contribution.

Table 7.1: Summary of Research Hypotheses Not Rejected

Hypothesis	Independent Variable	Dependent Variable	Relation
H_1a	Co-location	Time-to-Market	-
H_1a	CFT	Time-to-Market	-
H_1a	Team leadership	Time-to-Market	-
H_1a	Rewards and recognition	Time-to-Market	+
H_2a	Formal team briefings	Time-to-Market	-
H_2a	Organizational redesign	Time-to-Market	+
H_2a	Project management	Time-to-Market	-
H_3a	Computers/networks	Time-to-Market	-
H_3a	CAD	Time-to-Market	-
H_3a	Simulation	Time-to-Market	-
H_4a	DFM	Time-to-Market	-

It is important to keep in mind that while effectiveness might not be actually perceived by managers and team leaders, the CE practices may still nevertheless be contributing to reducing time. In fact, it is possible that without them the time required might increase. In order to avoid the ambiguity around practices and their effectiveness on different time measures it is important to set up metrics for measuring their effectiveness in companies. This study begins at sharpening the view for the metrics by defining cycle time in three specific ways.

While it is not surprising to find organizational redesign and rewards and recognition as ineffective practices for reducing NPD cycle time since they were also not significantly used practices, those practices that were found to be frequently used but not effective in reducing Time-to-Market were unexpected. Such practices include: team development, formal NPD procedures, and QFD. It is possible that NPD managers are using such practices because they lack a better substitute. In searching the literature, no data regarding the effectiveness of these practices were found.

7.2.2.1 – People Practices

Since not every practice contributed to the reduction of cycle time, the following discussion provides more detailed explanations for the individual relationships between the people practices and NPD cycle time.

In terms of the people practices there are studies that both contradict and support the positive impact of CE practices on the reduction of cycle time. The literature review uncovered many supporting studies for the use of CFT and co-location for reducing NPD cycle time. Those studies that contradict the findings of this research include the work of Kahn and McDonough (1997) and Karagozoglu and Brown (1993). Their research supports the finding that suggests that co-location may not be sufficient on its own for reducing time. Co-location is only one way to connect people. With improved information and communication technologies, virtual workplaces have become common in the workplace. People learn to adapt to them and interact with one another through them. Another reason for lack of support for co-location as a time reducing practice is the notion that over-communication and knowledge sharing can affect implementation and execution of tasks.

Similarly, CFT can also negatively impact time reduction. Karagozoglu and Brown (1993) found that while CFT contribute to the transcendence of information across boundaries, such teams increase tension and conflict, require more team skills and reduce management control. Such teams work better at certain stages of the project. Using CFT at wrong points of the project is likely to have varying results in terms of the benefits this practice provides (Karagozoglu and Brown, 1993). At the beginning stages, they assist product definitions and goal setting. At the final stages, they solve critical and frequent bottleneck problems.

As for rewards and recognition, findings in this research suggest that they lead to an increase in cycle time. This implies that NPD managers are possibly failing to link these rewards to the reduction of NPD cycle. In order for them to reduce cycle time, they must be linked to explicit CE performance goals, such as time (Zirger and Hartley, 1994).

With regards to team leadership, this practice is significantly ineffective in helping to reduce NPD cycle time. This might be because NPD managers find that teams have too much power and autonomy making it difficult for the organization to keep them on track.

7.2.2.2 – Process Practices

"The information process practices provide is essential for establishing the framework for direction setting in the NPD environment, and achieving CE goals". Process practices help to ensure that NPD process runs smoothly and that stages are overlapped as they should be in any concurrent engineering environment. According to Lynn et al. (1999), CE can cause delays in the NPD process if it is not conducted properly or not appropriately used in sharing information. The practices that administrate CE include formal NPD procedures, project management, team briefings, organizational redesign and customer/supplier integration. Each one contributes to the integration of functions and overlapping of stages in the NPD process. Essentially, they are the mechanisms for which overlapping, the most critical aspects of CE, is fulfilled. (Overlapping is more than just a practice for CE; it is one of the core definitions of concurrent engineering.)

Arguably the most important of the process practices is project management. The findings of this research found that project management was the most effective practice in reducing NPD cycle time. Research by Ainscough and Yazdani (2000) also shows that project management is associated with quicker development cycle times. This is an important finding as it confirms undertaking activities simultaneously can be challenging, but can become much more doable with strong project management capabilities.

Process practices that were either found to be at the bottom of the list of the significantly effective practices and/or not found to be significantly effective in reducing Time-to-Market, include formal team briefings, formal NPD procedures, customer/supplier integration, team development and organizational redesign.

While some researchers have found data to support the effectiveness of formal NPD procedures in reducing NPD cycle time (Lynn et al., 1999), this study found no significantly positive relationship between formal NPD procedures and their ability to reduce NPD cycle time. Leonard-Barton (1992) explains that "the core competencies of the formal process can manifest itself as core rigidities" – this applies to both formal NPD procedures and team briefings. The practices become detrimental to success when there is too much emphasis placed on them. It is perhaps for this reason why NPD managers do not find them to be very effective. This finding suggests that while practices are tempting for CE, NPD managers should avoid getting carried away, especially when they cause the undertaking of activities to be less flexible.

As for customer/supplier integration, despite Karagozoglu and Brown (1993) findings that such integration prevents delays in the NPD process, the literature review failed to find any support for its ability to actually reduce NPD cycle time. This, however, does not make it an unimportant practice. In fact this practice can help a company ensure that the product will be desired by the market. Not involving customers and suppliers might even make it impossible to develop the product at times. The trade-off when NPD managers use this practice might be between quality and time. Researchers might want to examine projects where customers and suppliers are integrated and in order to further study any residual savings in time that might occur due to their involvement.

According to Gupta and Wilemon (1990), process practices can either make or break the success of CE depending on the extent to which they are effective in increasing concurrency of activities and managing information flows. While a lack of process practices is negative for the success of CE, overemphasis of process practices can also lead to an overly rigid NPD process.

The literature review failed to find any support for the use of formal team briefings and the reduction of NPD cycle time. Although, team development is known to significantly improve the functionality of teams, there was no support found for its ability to reduce NPD cycle time. The same issue applies with organizational re-design. Other than its association with project management and team-orientation it has no relationship with NPD cycle time reduction.

Organizational redesign was found to be significantly ineffective in helping to reduce NPD cycle time. Probably the best way to justify this is the fact that organizational redesign does not take place overnight; it takes lots of planning and organizing. Once it occurs it requires change management, communication plans and organizational support. The time and energy that goes into adapting the organization to the new design is at the opportunity cost of the NPD activities at hand. This does not mean that organizational redesign is negative for an organization, only that it is not feasible to do it frequently. Organizations go through a great deal of change and efforts to find the right structure that will allow it to accommodate its development processes and then to stabilize once the appropriate changes have been made.

7.2.2.3 – Tools and Techniques

According to the findings of this research all of the practices, with the exception of CAM systems were found to contribute to the reduction of NPD cycle time. These practices include CAD, simulation, and computers/networks. Although the three tools and techniques are fairly close in their levels of effectiveness in reducing NPD cycle time, CAD was found to have the highest significant impact in reducing NPD cycle time, followed by simulation and computers/networks. This indicates that perhaps NPD managers are using these tools to gain more sophisticated insights as to possibilities surrounding the product. It suggests more emphasis on creating, designing and testing.

The findings of this research suggests CAD reduce NPD cycle time. While the literature explains that the tool reduces the need for long computational procedures and thus time (Karagozoglu and Brown, 1993; Liker et al., 1999; Zirger and Hartley, 1994; and Cordero, 1991), other researchers found that reducing the reliance on this tool is better for reducing time, especially if poorly implemented (Kessler and Chakrabarti, 1999; Tabrizi and Eisenhardt, 1993. These findings suggest that when using CAD, NPD managers should be careful not to get carried away with the endless possibilities it might offer. At some point the creating and designing stages will need to draw to a close in order to meet time and budget goals. Perhaps the solution for NPD managers is to develop strong project management skills that help put limit the scope of use of the tool.

For the effectiveness of computers/networks, Carter and Baker (1992) found that such tools/techniques also allow for automation which translates into time-savings. They allow for specifications, design parameters and other information to be transferred quickly from one team member to another. This is not a surprising finding, given how dependent the knowledge economy has become on computers/networks.

According to Carter and Baker (1992) and Clark and Wheelwright (1996), simulation helps to reduce NPD cycle time because it allows testing of specifications before the prototype is built and thus translates into less rework or recycling in later stages. Nevertheless not all researchers have found this practice to reduce time. Kessler and Chakrabarti (1999) found that testing in fact increases the time required for NPD. Again, similar to the use of CAD, these findings suggest that when testing and simulating the product a feasible scope must be set and specific results must be sought after. Otherwise, the product can be tested to death!

It is interesting to note that these three tools and techniques are also among the top six most significantly effective practices. This is contradictory to the findings of Gupta and Wilemon (1990) and Roberston and Allen (1993) who found that they could have a negative impact on NPD performance. They noted that tools and techniques are not necessarily appropriate for NPD due to the uncertain nature of the NPD process and the efforts needed for tools and techniques. Tools and techniques require time to study feasible options within the context of project and organizational needs and to implement.

Part of the reason for this contradiction has to do with the level of skills and know-how that are required when implementing new technologies. According to Statistics Canada's 1999 Survey of Innovation, one of the largest challenges for Canadian companies was the rapid changes in production and organizational technologies. Also among the top challenges was the lack of skilled and experienced personnel. As technologies become more sophisticated the level of skill and experience that is needed to operate them increases. Without the right background an organization can have an extremely difficult time operating the technology.

7.2.2.4 – Formal Methods

Formal methods are generally used to help reduce NPD cycle time by assisting with the integration and coordination of concurrent activities (Hauser and Clausing, 1998). DFM was the only practice in this group found to be significantly effective in reducing NPD cycle time.

The result of this research regarding QFD and its ineffectiveness in contributing to time reduction is interesting. QFD allows NPD managers to analyze customer and other requirements for the product and avoid rework or recycling at later stages of the process (Griffin, 1993). The same can be said for FMEA – as it helps to reduce errors and possible delays in the developmental stages of the NPD process. While research by Hauser and Clausing (1998) shows that a majority of firms studied used QFD to assist specifically with the rapid development of new or significantly improved products, QFD had no relationship with the reduction of NPD cycle time in Trygg (1993). Clearly the results with regard to the effectiveness of QFD in reducing cycle time are mixed.

In the case of DFM, the only formal method to have a positive relationship with the reduction of Time-to-Market, the practice is also highly associated with design-oriented activities. Thus, had there been sufficient data to test it against Development Time it would have been expected that this practice would help reduce that time measure. DFM helps in reducing the number of parts required in the product, ease of assembly, the amount of rework and the amount of redesign required (Calabrese, 1999; and Trygg, 1993). This finding is interesting because it suggests that DFM may also help to reduce time at earlier stages such as during market finding or new product strategy. Further research could focus more on how development-related practices relate to the reduction of time in earlier stages. Especially since some research suggests that DFM increases NPD time (Keşsler and Chakrabarti's, 1999).

7.2.2.5 – Effectiveness of CE Practices By Type of Innovation

The final hypothesis stated in this research has to do with the differences in the effectiveness of CE practices in reducing NPD cycle time for incremental versus radical innovation. Similar to the previous four hypotheses, the fifth one was also divided into three sub-parts. These five hypotheses posited that people, process, tools and techniques and formal methods will all have different effects on reducing:

a) Time-to-Market
b) Concept-to-Customer Time
c) Development Time

While the individual effectiveness of the practices in reducing Concept-to-Customer Time and Development Time could not be assessed the findings indicate that CE practices do contribute to reductions in these time measures.

The findings relating to Time-to-Market confirm part of this fifth hypothesis; that CE practices have different effects on NPD cycle time (i.e., Time-to-Market) depending on the type of innovation. These findings corroborate the findings of other research as well. Montoya-Weiss (1998), for example, found that there were differences placed on the importance of practices by type of innovation. This finding suggest that not only do incremental and radical innovation differ in the importance placed on NPD stages, but that there are some differences in the emphasis that should be placed on certain practices when time is a performance goal.

Table 7.2, below, summarises the confirmed hypotheses based on whether the mean for effectiveness was significantly greater than the mid-point (3) of the survey scale. A negative relation depicts a reduction in NPD cycle time when a particular CE practice is used.

Table 7.2 – Summary of Hypotheses Not Rejected, by Type of Innovation

Hypothesis	Independent Variable	Moderating Variable	Dependent Variable	Relation
H_5a	CFT	Incremental	Time-to-Market	-
H_5a	Team leadership	Radical	Time-to-Market	-
H_5b	Project management	Incremental/ Radical	Time-to-Market	-
H_5b	Formal team briefings	Radical	Time-to-Market	-
H_5c	CAD	Radical	Time-to-Market	-
H_5d	DFM	Radical	Time-to-Market	-

The findings show that radical innovation projects are more likely to receive a greater impact from CE practices than incremental innovation projects. For incremental innovation there were only two practices that were found to be significantly effective in reducing Time-to-Market; these were project management and CFT. For radical innovation there were five significantly effective practices; project management, DFM, team leadership, CAD and formal team briefings.

When testing if the means for effectiveness of the practices differed by type of innovation, three statistical differences were found for project management, team leadership, and rewards and recognition.

The only CE practice that had a significant positive effect on Time-to-Market for both types of innovation was project management (process practice) – i.e., the means were significantly greater than the mid-point (3) of the survey scale with regards to effectiveness. This finding further confirms the importance of project management regardless of type of innovation developed. Nevertheless, project management was found to be more effective for radical innovation in reducing Time-to-Market. This is understandable since radical innovation entails more ambiguity and uncertainty to be managed. This finding suggests that when developing radical innovation, NPD managers will want to be very clear with project objectives and outcomes, timelines, resource allocations, etc. – all important project management activities.

Research by Kessler and Chakrabarti (1999) supports the use of team leadership for reducing time for radical innovation instead of for incremental innovation. Due to higher levels of uncertainty and complexity associated with radical innovation, empowerment is more effective for this type of innovation. Formal team briefings allow increased communications and clarity of messages (Kessler and Chakrabarti, 1999). For incremental innovation, less communication helps prevent unnecessary complexity and frequent interruptions of tasks. In incremental innovation, roles and tasks are less ambiguous. NPD managers have the benefit of knowing that these practices might not be needed for incremental innovation, allowing them to spend time on other contributing practices.

With more uncertainty associated with radical innovation, however, a higher level of communication and coordination is needed than with others. This finding suggests that part of the key to reducing NPD cycle time for radical innovation is to find a practice that helps reduce the ambiguity that makes the radical innovation project troublesome. By lowering uncertainty and ambiguity, activities can be fulfilled more rapidly.

For rewards and recognition, this practice was not found to be statistically significant in terms of effectiveness for either radical innovation or incremental innovation, nevertheless the mean for effectiveness in radical innovation projects was significantly higher than for incremental innovation projects. This difference could suggest that rewards and recognition can be linked to performance goals so long as they are used properly. In radical innovation projects, where outcomes are not easy to predict, setting rewards for specified goals maybe one way of establishing clear objectives and goals that otherwise may be very difficult to work towards.

These findings are expected given the need for greater flexibility and support for the integration of functional activities, particularly between design and manufacturing (Liker *et al.*, 1999). In order to achieve the needed levels of flexibility, support and coordination, additional practices are required.

In addition to these findings, there are some practices which were statistically significant for one type of innovation but not the other that are worthy of mention even though the difference in the means for radical versus incremental innovation is not statistically significant. These practices include DFM and CFT.

According to the findings of this research, DFM is another practice that has different effects on NPD cycle time for incremental and radical innovation, although the difference is not statistically significant. NPD managers of radical innovation projects were more likely to indicate that it contributed to reduction of Time-to-Market. It is interesting to note that while Moffat (1998) did not find any significant relationship between DFM and NPD cycle time, her research found that incremental innovation tend to receive more support from this practice. This result is not surprising. In radical innovation projects, the concept is unclear and unknown making the beginning stages of the NPD process very fuzzy. The fuzzier it is the more likely people are to focus on adapting to the ambiguity rather than planning for the stages ahead. The more ambiguous the current situation, intuitively the harder it is to plan for future steps.

Nevertheless, when asked about its effectiveness to reduce Time-to-Market in this research, NPD managers of radical innovation projects were more likely to score DFM as an effective practice for reducing time than NPD managers of incremental innovation projects. It suggests that future planning for radical innovation projects can provide significant advantages because it is another means to make later stages less fuzzy and prevent time-consuming problems that could present themselves later on. While people often take for granted the time-savings that can occur if ambiguity is managed and planning is done at earlier stages, the research findings suggest that perhaps some NPD managers are taking advantage of such opportunities. They are more accepting of possibly starting out of the gate more slowly in order to avoid problems later on.

Although many other measures of CFT are needed to confirm the finding of this research, one practice that was statistically significant in terms of effectiveness in reducing cycle time for only incremental innovation was CFT. While there was no statistical difference between the means for effectiveness for each type of innovation, it is very interesting to note that that the finding could suggest that CFT is a multi-disciplinary approach that may not be appropriate for reducing NPD cycle time for radical innovation projects. This was a highly unexpected finding, since increased communication helps increase flexibility and facilitate the development of radical innovation projects (Kessler and Chakrabarti, 1999). Eisenhard and Tabrizi (1995) and Griffin (1997) also found that cross functional teams are more effective in reducing cycle time in project of higher uncertainty.

A CFT is a core component of CE and is one way of increasing communication. In support of the findings of this research, it is also possible that due to the uncertainty, discussions, and disagreements that occur in regards to radical innovation, diffusion of knowledge takes more time. Individual team members might also need more time to work on their ideas and then transmit and explain these ideas to others. CFT also increases tension and conflict, requiring more team skills and reducing management control (Karagozoglu and Brown, 1993).

One finding where there was no statistical difference found between the means for effectiveness for incremental and radical innovation was CAD. CAD was also not found to be statistically significant for either incremental or radical innovation in terms of effectiveness in reducing Time-to-Market. This practice, however, was statistically significant in terms of use for both incremental and radical innovation and was significantly more used in radical innovation then incremental. The research suggests that use and effectiveness of CAD seem to contradict.

The lack of effectiveness of CAD systems is also supported by other research in the literature. Although it is critical for fostering CE (King and Majchrzak, 1996) CAD tools can slow down the development process particularly for those products with greater uncertainty (Tabrizi, 1994; Eisenhardt and Tabrizi, 1995). However, as explained earlier, part of the reason for this might be due to the fact that CAD systems require skilled and trained personnel. They also require the right processes in place for using the technology at the right time. Often it is not the technology itself that is the problem but rather the way in which it is being used and who it is being used with.

7.2.3 – Gap between Frequently Used and Effective CE Practices

The final research question examines the gap between those practices used extensively in NPD projects and those found to be significantly effective in reducing NPD cycle time. Essentially this third research question sets out to answer the difference in the findings for the first two research questions. As explained in the literature review there can be a number of reasons for this gap (e.g., lack of time, knowledge or resources hindering the proper use of the practice, or poor alignment between practices and needs).

There is two ways of examining the gaps between the frequently used practices and the effective practices. One way is by comparing which practices were not statistically significant (i.e., where the means were greater than the mid-point (3) of the survey scale) for both use and effectiveness in reducing Time-to-Market. The second is by examining those practices whose use and effectiveness are not statistically significant in terms of correlation. The following section describes the findings for both types of analysis.

This research found that while NPD managers frequently use formal NPD procedures and QFD (based on the mean being significantly higher than the mid-point (3) of the survey scale), they do not find these practices to be effective in reducing NPD cycle time (in particular Time-to-Market). In the previous section of this chapter, reasons for why they are not effective were provided. The gap itself is partly due to organizational tendencies to get caught up in bureaucracies and support mechanisms.

Formal procedures and QFD are both methods of formalizing business operations. Some of the most effective organizations take advantage of formal business practices for different reasons. Nevertheless, too much formalization can lead to a lack of focus on the market, on customer demands, and on changes in the competitive environment. In such cases formalization facilitates processes but could arguably be facilitating the wrong processes. This creates a "perverse" behaviour, where people emphasize rules and "doing things by the book". What they probably should be doing, however, is actively challenging old ways of doing things and looking for solutions that have not already been found.

Based on the correlation analysis, the findings suggest that there are gaps between the use and effectiveness of the following five practices: simulation, CFT, team development, formal team briefings, and co-location. It is interesting to note that team development is the only practice that was not statistically significant in terms of both frequency of use and level of effectiveness. The gap between use and effectiveness for CFT, formal team briefings and co-location are difficult to interpret especially since use and effectiveness are significantly greater than the mid-point of the survey scale. Further research and a larger sample size might help to explain whether or not the use and effectiveness of these practices are truly not correlated.

In the case of simulation it is not surprising that those managers that are using the practice might not also believe that it is highly effective in reducing Time-to-Market. As explained earlier, simulation does reduce the time required for problems that might occur later on in the NPD process but it also requires actual time to do and use. Essentially, NPD managers might have difficulty assessing time that was saved as a result of potential problems that did not occur by virtue of simulation and other numerous due diligence activities, versus time that was actually used up. While NPD managers are aware that problems can and often do occur, unless the probability of those problems can be assessed, NPD managers might be more predisposed to thinking of simulation as a time-spending activity rather than a time-saving one.

In the case of team development, the fact that there is no gap between the frequency of use and effectiveness of the practices is not surprising. This can be a result of the lack of commitment that exists in Canadian firms to invest in training and development. The data shows that organizations in Canada, like other OECD countries, under invest in such areas (The Conference Board of Canada, 2004b). In part, some organizations lack the required financial capital to invest but often their under investment is related to a lack of conviction in the returns they will get. The return to the bottom line has been proven empirically – showing companies that invest more in training also have higher corporate performance than those that under invest.

Firms might also be reluctant to invest in team development and other similar types of training, if they fear loosing their trained workers to other firms. On the other hand, investment in training and development can be used as incentives for attracting workers from other firms or even keeping current workers productive and satisfied.

One interpretation of the data is that NPD managers might not recognize the long-term benefits of training and team development. Or, perhaps the budget allocated to them does not allow for such investments. Typically, economists might argue that for every hour an employee spends in training the opportunity cost is an hour lost from regular business activities. But this is not entirely true. Training and development are one of the key ingredients to increased productivity and efficiency. By strengthening people's ability to work smarter instead of harder, gradually the impact grows over time, resulting in time reductions in the NPD world. Such benefits are not quick fixes that occur overnight, making it more difficult for NPD managers to notice and attribute to training.

On the other hand, team development might also be seen as a red-herring by some NPD managers. The literature expresses clearly the stages that teams typically go through before becoming functional. The transition through the stages of development might be facilitated by training but not eradicated. NPD managers might fail to recognize how training can overcome these challenges and might prefer to allow teams to adapt overtime.

The key message for NPD managers is that while they should recognize that teams require time to progress through the stages of development, training can also significantly increase the capabilities of the team. The recommendation here, as made in other research studies, is to invest more in the training and development of teams.

Where there are no gaps based on statistically significant correlations between use and effectiveness is with the "harder" more tangible practices whose use and effectiveness may be easier to detect, such as DOE, formal NPD procedures, CAD, CAM and QFD. The fact that their use and effectiveness in reducing Time-to-Market are strongly linked indicates that these formal methods and tools might be easier for NPD managers to identify the results they are getting when putting them into use. Researchers in the future might want to look at other ways of measuring the gap between use and effectiveness of practices that are "softer", related more to people and processes. These practices are sometimes more difficult to assess and see that they are occurring (e.g., team leadership). NPD managers should consider that although the impact of practices might not be as easily measured as others, it does not mean that their use does not also contribute to impacts on time-savings. This is where experience and experimentation in using CE practices is handy, in addition to trusting research findings.

7.2.3.1 – Gap between Frequently Used and Effective Practices by Type of Innovation

Akin to the first two research questions, the differences in the gaps between frequently used and effective practices between radical and incremental innovation were examined based on the statistical significance of the means (i.e., the extent to which the mean for use and effectiveness were significantly greater than the mid-point of the survey scale) and correlations between use and effectiveness of the practices.

The findings from the correlations show that for the majority of the practices used in incremental innovation the use and effectiveness of the practices are not correlated. The findings regarding means that are significantly greater than the mid-point (3) of the survey scale, suggest that there are gaps in use and effectiveness for thirteen practices. For radical innovation the gaps exist for only nine of the practices. In order to focus on those gaps that involve statistically significant practices in terms of use or effectiveness, the discussion is focused on those practices that are being frequently used but that do not have any positive impact on the reduction of NPD cycle time or vice versa.

While all of the practices that were found to be significantly effective were also found to be frequently used for incremental innovation, the differences are between those practices that are frequently used but that are not significantly effective. These practices include co-location (people), team leadership (people), formal team briefings (process), formal NPD procedures (process), CAD (tool/technique), computers/networks (tool/technique), simulation (tool/technique), and DFM (formal method). It is interesting to note that while tools and techniques are frequently used, NPD managers do not believe that they are effective in reducing NPD cycle time. This finding suggests that as organizations depend more heavily on tools and techniques NPD managers take for granted the extent to which they actually reduce time. The fact that co-location and team leadership are not effective but are used frequently could be a result of too much time spent on co-location and perhaps not enough time spent on team leadership. If a team is not being appropriately empowered, it might be that the end result is similar to the team not being empowered at all. The finding might imply that companies need to be prudent not too overuse a practice as well as to use it right. With regards to the process practices and formal methods, the lack of perceived effectiveness might be a result of too much bureaucracy emerging from these practices or simply that these practices are also taken for granted as they help strengthen and establish the organizational processes that are needed to undertake NPD activities.

For all of these practices the ineffectiveness of the practices in reducing NPD cycle time can be a result of the overuse of practices. NPD managers and researchers might want to consider how the frequency of use can contribute to a lower effectiveness these practices in reducing NPD cycle time for incremental innovation.

The practices that were found to be effective (and frequently used) include only CFT and project management. This is a highly expected finding since the literature elaborates on the effectiveness of CFT and project management and the data suggests that NPD managers use these practices often. Again, this is further support for the importance of these practices. For the other practices that were not found to be effective it could be because they are not used frequently enough for NPD managers to know how to evaluate them on their effectiveness.

For radical innovation, all of the practices that were found to be significantly effective were also found to be frequently used. The practices that were not found to be effective (but that were frequently used) include CFT (people), team development (people), co-location (people), computers/networks (tool/technique), and simulation (tool/technique). These results were highly unexpected, especially the results regarding CFT and team development. The findings suggest that when a product is entirely new to the organization the CFT does not help to decrease cycle time, despite the fact that NPD managers continue to use it.

This may be another case of an essential component being taken for granted or it might be that multi-disciplinary teams might actually add to the confusion when complex ambiguous tasks are at hand. This does not mean that they should be abandoned altogether; rather it means that in the case of radical innovation projects NPD managers might want to look into additional practices that support teams or refrain from having the team convene too often. There might be an optimal level for meetings in radical innovation projects. This interpretation is in some way contradictory to the data that suggests that NPD managers do not find team development to be effective in NPD cycle time reduction. In reality, it is understandable that training and development take time and that it should not occur in the middle of a highly rushed project where timeliness is a measure of success. NPD managers should consider developing their teams ahead of time or when workload is lighter. The finding regarding these practices brings forward a very important point: there are practices that are important, used frequently but not always effective in reducing cycle time.

These findings suggest there are practices that are core to CE and practices that appropriate when focusing on NPD cycle time reduction. Some practices might help achieve other NPD performance goals, while others are used for speed-to-market. Future research could emphasize those projects whose NPD managers are focused on achieving NPD time goals and explore perceptions as to why the practices do not contribute to the reduction of cycle time.

The practices that are effective in reducing NPD cycle time include team leadership, project management, formal team briefings, CAD and DFM. These findings suggest that NPD managers recognize the practices that help to reduce NPD cycle time (as suggested by other studies) and continue to use them for this reason. Researchers might want to examine whether this is because of the nature of the practices themselves or the frequency of use of the practices. One could examine whether they are effective in reducing time because NPD managers use them frequently and if NPD managers consider time reduction as one of their major performance goals. As performance goals are difficult to isolate from one another, researchers might also consider investigating the impact of these practices on multiple performance goals, other than just time. This would be of particular importance to NPD managers focused on other NPD goals (e.g., cost reduction). It could also help them decide whether or not they should abandon certain practices that are effective in attaining one performance goal over another.

In order to further extend the literature in this area, researchers might also want to look at projects whose NPD managers are employing different types of practices and the effectiveness of those practices. They might also be likely to suggest other practices for NPD managers to use when reducing time. This is important since effectiveness is almost impossible to measure unless use occurs. This means that the study of effective practices is limited to the use of practices. By tapping into a wider pool of practices used, more insights may be provided for NPD managers seeking to employ more practices that reduce time.

When looking at the differences between radical and incremental innovation, there are fewer differences between the frequently used practices for incremental and radical innovation than for the effective practices. These differences and possible reasons for them were explained in previous sections. Essentially there are more gaps between effective and frequently used practices for radical innovation than there are for incremental innovation. In part this is because of the nature of uncertainty around radical innovation. NPD managers try to use as many of the different tools and practices at their disposal in order to eliminate uncertainty and risk. These projects rely heavily on knowledge creation, knowledge diffusion and idea transformation; activities that require a great deal of support and management.

Chapter 8 – Conclusion

The purpose of this research is to empirically investigate which CE practices are most likely to reduce NPD cycle time, and to examine the differences in the relationships between the practices and cycle time for incremental and radical innovation. Four research questions are associated with this purpose as introduced in chapter three:

- What CE practices are frequently used in NPD?
- To what extent are CE practices effective in reducing NPD cycle time?
- What gap exists between actual usage and perceived usefulness of practices?
- How does type of innovation moderate the relationship between NPD cycle time and CE practices?

The investigation of these research questions was accomplished through a survey of 20 Canadian manufacturing firms in the electronic parts and components industry that use CE in incremental and/or radical innovation.

The study examines the effects of four groups of practices on NPD cycle time. Using Griffin's (1993) cycle time measures, NPD cycle time is defined using three measures of time; Time-to-Market, Concept-to-Customer Time and Development Time. These times are defined by stages of the NPD process. Time-to-Market covers the entire process from market finding to production; Concept-to-Customer Time covers new product strategy to production; and Development Time ranges from detailed design and prototype development to production.

The analysis of the data was conducted using t-tests and correlation analysis of survey results collected from NPD managers of electronic parts and components manufacturing companies.

8.1 – Research Benefits

Developing new or significantly improved products often requires additional sets of skills and activities that organizations do not always have. As the need for more resources, skilled employees, and NPD activities increases, the greater the balance between different performance goals that is required. It is impossible to pursue all NPD performance goals; they need to be prioritized. While this research does not focus exclusively on those organizations whose focus is time, it does examine the CE practices that help to reduce NPD cycle time in organizations that compete in industries with very short product life cycles and rapid NPD cycle times.

According to Kessler and Chakrakbarti (1994) time was one of the least studied factors in the new product development literature. Over the last ten years, however, it has become an area that has attracted and continues to attract a lot of attention. This is in part a consequence of markets becoming much more competitive and product life cycles shortening. Time is affecting the prices at which products are sold and the extent to which they meet consumers' expectations. Just think about how rapidly hand-held applications, cellular phones and micro-electronic devices, for example, have changed in both price and offerings in the last three years.

This research contributes to that body of research, because working more quickly is challenging still for many firms. Products of a given firm are not only taking over the products of its competitors but in many cases firms are replacing their own products with new and better ones more and more rapidly. Knowing what tricks to use is key.

The findings of this research suggest that while most practices are perceived to be important for reducing NPD cycle time, fewer practices actually reduce cycle time. This research examines CE practices that are used frequently, those that are effective in reducing NPD cycle time and the gap between frequently used practices and effective practices. Such analysis was done for two different types of innovation; radical and incremental. By identifying these practices, this research helps NPD managers become more purposeful in their use of practices when trying to deliver new or significantly improved products into the market more quickly. As well, as identify the best practices to use when developing radical or incremental innovation.

This research examines if incremental or radical innovation change the relationship between time reduction and the practices. The interesting element in this part of the study rests in the fact that many regard the production of incremental innovation instead of radical innovation as a practice itself for reducing NPD cycle time, yet in this study it is regarded as a moderating variable. The study provides some statistical evidence and backing for the perceptions of NPD managers regarding the impact of type of innovation on the relationships between NPD cycle time and CE practices.

This research studied the practices summarized by Poolton and Barclay (2000) and examined by other researchers. The practices belong to four main categories: people practices, process practices, tools and techniques and formal methods.

Time was also studied in terms of different categories based on a concept suggested by Griffin (1993), where NPD cycle time was divided into Time-to-Market, Concept-to-Customer Time and development. By breaking down NPD cycle time into three different time measures (i.e. Time-to-Market, Concept-to-Customer, and Development Time) each beginning with a different stage of the NPD process, the results obtained from this study will indicate the direction of the relationship between CE practices and NPD cycle time. The results might suggest that certain practices are more useful than others for reducing time depending on where in the NPD process the measurement begins. This is unique to most of the literature that exists already on NPD performance and practices because very few have yet looked beyond the basic relationship between the two.

Another benefit of this research is its contribution as a foundation for detailed future research using a time framework that no one has used before. It also serves to account for time reduction practices in the Electronic Parts and Components industry in the Canadian context. Although it is admittedly not an exhaustive finding of all practices, it provides a simple guideline for firms oriented to time reducing practices or wanting to focus on those CE practices that reduce NPD cycle time.

8.2 – Research Limitations

The greatest limitation of this study is the limited number of responses collected. It was difficult getting respondents to complete the questionnaire. There were only selected individuals that could be targeted since it was important that the respondents be knowledgeable of the NPD product and the CE practices used. Another reason for the low response rate was time pressures for the companies. Few companies were willing to sacrifice the time needed to answer the questionnaire. This smaller sample size made it impossible to do sophisticated statistical analyses. Even the reliability and validity of the data is lessened due to the small sample size. The conclusions, therefore, are also less significant and generalizable on the population.

One of the limitations of this research had to do with the measures used to examine the relationships between CE practices and the different categories of time. Only one of the survey questions asked specifically about the practices that reduced Time-to-Market. There were no equivalent questions for Development Time or Concept-to-Customer Time. Future research could ask this same type of question for the other two cycles of time. It might also be helpful to examine what practices work best in what stages.

The method of measuring cycle time presents another limitation for this study. In this research NPD cycle time was measured in terms of Time-to-Market, Concept-to-Customer Time, and Development Time. These are all internal time measures that end at the production stage.

With regards to the time measures, another limitation had to do with asking NPD managers to evaluate by the percentage to which Time-to-Market, Concept-to-Customer Time, and Development Time were reduced due to the adoption of certain CE practices. Since these are all based on perception, these results must be interpreted with caution. A much larger sample size would have helped account for the variances in responses in order to come up with more accurate averages for the group. Even quantitative measures would increase the reliability of the responses. In this study, they were all based on perception.

8.3 – Future Research

This study focused on firms belonging to the Electronic Parts and Components Industry in Canada. Future research could focus on firms from other sectors and/or other countries.

In future research, where a larger number of responses would be collected, different data analysis techniques could be performed on the responses provided. There are a number of different statistical techniques that are used to analyze the data. According to the study by Kessler and Chakrabarti (1999), which looked at the differences of specific factors on NPD cycle time for both incremental and radical innovation, split factor analysis was used to separate the findings for the two groups. Factor analysis could also be used to reduce the practices to lesser variables.

Looking at Appendix VII a number of different studies that were done on the factors impacting NPD cycle time, used regression and correlation as methods of data analysis. Regression would be another data analysis technique for testing if there is a relationship between CE practices and NPD cycle time. Depending on the number of responses collected the Pearson correlation coefficient could also be used in order to examine the "strength of association" between NPD cycle time, measured in terms of the three variables, and the CE practices (Gerwin and Barrowman, 1991).

The list of CE practices was not exhaustive nor did it provide a great deal of variety. Although they are commonly used practices cited throughout the literature, they are mostly design-based practices and are based on the list provided by Poolton and Barclay (2000). In future research, other practices could be considered, especially those that more marketing and manufacturing oriented.

Finally, the inclusion of incremental innovation as a moderating variable for the relationship between CE practices and NPD cycle time presents another area for future research. Incremental innovation is considered a technique for NPD cycle time reduction. Some researchers have found them to be a useful characteristic of IPD for reducing cycle time. This is discussed in further detail in the following section.

8.3.1 – Moderating Variables

Finally, the discussion of moderators has been very lightly approached in this research. The moderator considered was innovation type; furthermore only two types have been considered; incremental and radical innovation. There are a number of other moderators that affect the relationship between CE Practices and NPD cycle times.

Concurrent Engineering practices that reduce NPD cycle time do not occur in a vacuum. They combine with additional factors to generate greater performance results, which impact the effectiveness of these practices on NPD cycle time. In product development projects, elements that moderate the effectiveness of CE practices on final performance outcomes can be categorized into three groupings: environmental elements, organizational elements, and project characteristics. These three categories contribute to the complexity, novelty and uncertainty that impact CE practices.

The *external environment* may be composed of customers, technology, suppliers, and competition, which all act as sources of uncertainty. At the *organizational level*, the type of organizational structure can impact the success of CE practices even though the type of structure chosen can also be identified as a CE practice. Mechanistic bureaucracy, formalization and differentiating mechanisms can have a negative impact on the ability of CE practices to reduce NPD cycle time (Hull *et al.*, 1996). Differentiating mechanisms include "horizontal distinctions, such as job specialists, and vertical limits, such as links in the hierarchical chain of command" (Liker *et al.*, 1999). At the *project level*, three important dimensions facilitate the explanation of those variables that affect the ability of CE to successfully achieve project goals such as Time-to-Market: 1) Complexity, 2) Novelty, and 3) Project Definition (e.g. Barclay and Dann, 2000; Tatikonda and Rosenthal, 2000).

8.3.2 – Intervening Variables

Intervening variables are hypothetical, often internal, states that are used to explain relationships between observed variables such as independent and dependent variables. They are as interpretations of observed facts, but not facts themselves; they create the illusion of being facts. Examples of intervening variables include notions such as learning, memory, attitude, motivation, knowledge, understanding, intelligence, expectations, etc. Zirger and Hartley (1994) state that information processing and motivation are two factors that interfere in the relationship between techniques for reducing NPD cycle time and actual reduction of cycle time.

The information processing capability includes: the extent of information sharing that crosses functional boundaries and enables team members to understand product requirements, limitations and capabilities; the timeliness of information processing early on in the development process; and the speed of decision-making (i.e., decisions made at lower levels of the chain of command). Without information sharing and processing done in a timely matter CE practices may be unsuccessful in overlapping NPD activities and reducing cycle time.

Motivation comprises of explicit goals (i.e. setting project goals as subordinate to the main goal), goal congruence (i.e. integrating individual tasks to achieve a particular goal), linking rewards with performance (i.e. increasing the tendency to accomplish certain tasks by increasing the expectation that the outcomes of the tasks will be favourable to an individual), and control over the entire process (Zirger and Hartley, 1994). The suggestion here is that without goals and reward linked accordingly to them, CE practices are used by staff that lack direction or reason for employing the practices as a means to achieving the desired ends (Vroom, 1964).

If the researcher were to consider these variables, the same style of study could be performed. The relationship between CE practices and NPD cycle times could be investigated under the moderating effects of the environmental factors, organizational factors and/or project level factors, and/or the intervening effects of motivation and information processing. These factors are among the many other factors that could be studied in future research.

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APPENDICES

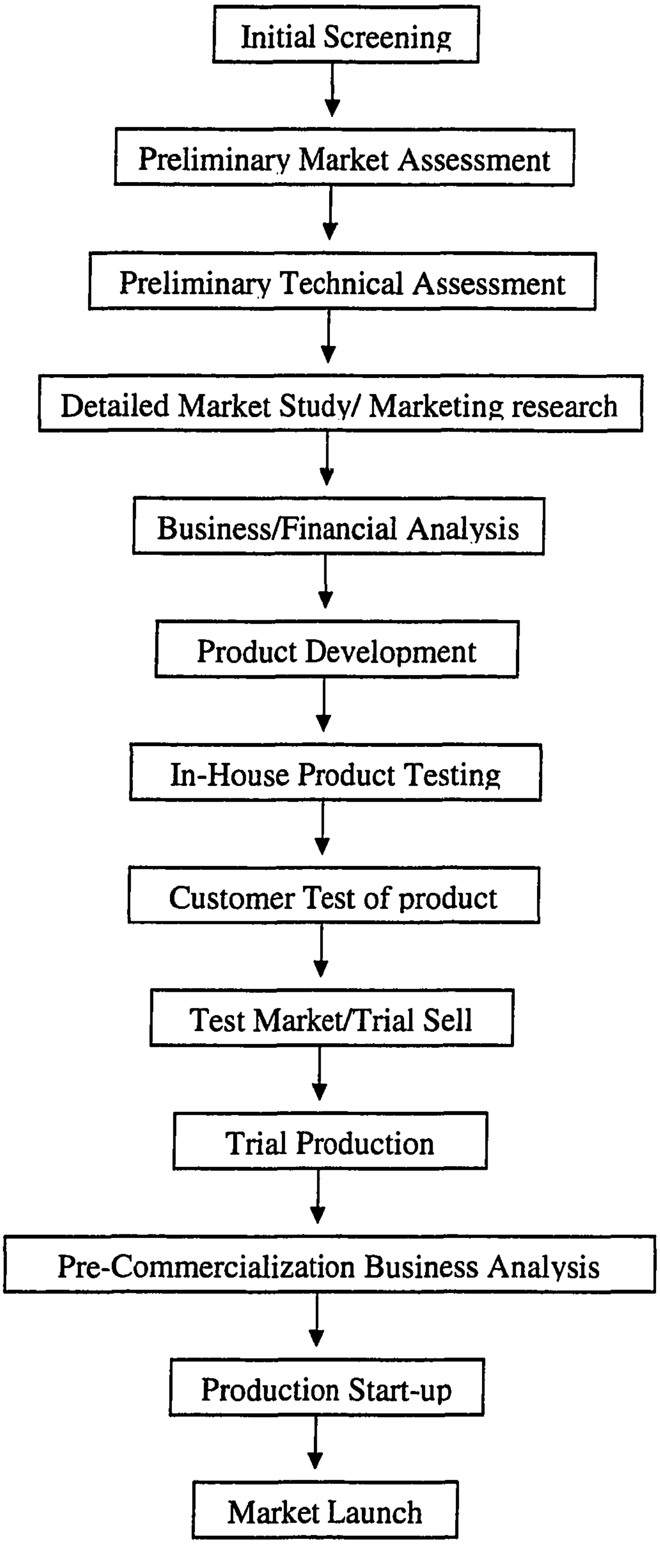
APPENDIX I

List of Acronyms

AMT – Advanced Manufacturing Technology
ATE – Automated Test Equipment
CAD – Computer-Aided Design
CAM – Computer-Aided Manufacturing
CCT – Concept-to-Customer Time
CE – Concurrent Engineering
CFT – Cross-Functional Teams
CIM – Computer-Integrated Manufacturing
COLOC – Co-location
COMPU – Computers/Networks
CSINT – Customer/Supplier Integration
DFM – Design for manufacturing
DOE – Design of Experiments
FMEA – Failure Modes and Effects Analysis
FRMPR – Formal NPD Procedures
FRMTB – Formal Team Briefings
IPD – Integrated Product Development
NPD – New Product Development
NR – Not Rejected
OECD – Organization for Economic Co-operation and Development
ORGRE – Organizational Re-design
PM – Project Management
QFD – Quality Function Deployment
R&D – Research and Development
REWRD – Rewards and Recognition
Sig. – Statistical Significance
SIMU - Simulation
SPSS – Statistical Package for Social Science
TMDEV – Team Development
TMLEA – Team Leadership
TPP – Technology Product and Process
TTM – Time-to-Market

APPENDIX II

Cooper (1990) – Thirteen Stages of NPD process



APPENDIX III

NPD Stage Definitions (Kumar *et al.*, 1994)

Market Finding Stage: The starting point for the innovation process is market finding. The decision to expand the market share or to maintain it, in the face of increased competition is made. Customers suggest either adding new features or reducing the price. The input is provided by marketing functions to future plans and actions for new product development.

Technology Research Stage: The research group acts on the idea suggested by the marketing department to determine the idea's technical and commercial feasibility. R&D then suggests more than one design alternative, and obtains feedback from the marketing department. Once marketing and research and development reach a consensus, R&D finalizes the product specifications and estimates the development cost, the unit cost, and the cost to customers. They also estimate the development time. The technology department traces the trend in the industry and determines the market need.

New Product Strategy Stage: Once the marketing and R&D departments reach a consensus about the technological feasibility of the product, the strategic role of the product is determined. After a company assesses the feasibility of a product, the development of a strategic perspective enables a product manager to define new product roles. Often, the business situation is analysed by holding either formal or informal brainstorming sessions. The involvement of the departments and managers in this process varies from firm to firm. However, the major participants are the owners and heads of engineering, R&D, and marketing. In general, brainstorming sessions include questions such as What are the unique features of the product? How has the market changed since the firm started? What are the manufacturing costs? Is it justified for the firm to spend the money to develop the product? How long will it take for the product to prove profitable? What competition will the new product face in the future? Sometimes, if the product does not meet all the criteria used in the business analysis, the firm looks for possible adjustments. The firm spends more time up front to define the product's features, performance, and costs. At least two or three meetings are held before all the departments come to an acceptable agreement, and receive top management's approval. All the departments get involved at the early stages of the innovation process.

Design Stage: This stage is normally made up of two steps: preliminary design and detailed design. This stage involves creating paper drawings of the potential product. The design is then subjected to a preliminary design review, which is conducted by senior managers from the engineering, production, and marketing departments. The engineering department ensures that the design includes its original intent; marketing ensures that there is a provision for the maximum number of customer features; manufacturing looks into the manufacturability aspect of the product. The preliminary design is followed by the detailed design, which, in some firms is also called the critical design. Basically, detailed design for hardware involves putting all the circuits together. A formal review called the detailed design review is conducted; this review primarily involves production, quality assurance, and engineering personnel. Marketing sometimes participates simply to keep aware of any changes made since the preliminary design review or of any new features being added. Adding new features bring the whole process brings the whole process back to the preliminary process stage. Changes at this stage cost little, so firms incorporate more changes at this point. Both the preliminary design review and detailed design review are documented.

Prototype Stage: Once the design has been scrutinized, a prototype, which is a trial model of the final product, is developed. The prototype is subjected to certain test to ensure that all features are incorporated in the model and that it is manufacturable. Tests are also conducted to determine the reliability and serviceability of the product. To ensure reliability, a quality assurance group performs life tests/stress tests, in which the product is stretched beyond its design limits to discover its ultimate limits. The prototype is also made available to the service department, which ascertains the serviceability of the product. Based on the problems detected, the prototype is redesigned. A cost-analysis is also performed at the prototype stage to justify every feature. Firms give their prototype to their customers and enquire whether or not the product meets customer requirements. These customers provide feedback directly to the firm's engineering department, and this feedback serves as a pre-qualification of the product by a limited number of customers.

Pre-Production Stage: This stage normally involves a pilot run in which only a few units are produced ; this is the first time the product reaches the production line. There is maximum interaction between the manufacturing and engineering department during this stage. The aim is to put everything together quickly in order to mass-produce.

Production Stage: The role of production is not only to produce and deliver the final product but also to be involved in many up-front activities. The production and engineering departments have formal monthly meetings and frequent informal meetings during development process. Within production, testing is reported to be an important activity. Once the pilot production run proves successful and more orders are procured, full-scale production starts.

Product Launch Stage: This is the last and most integral part of the marketing activities carried out parallel to the product development process.

APPENDIX IV

Generic Product Development Process (Ulrich and Eppinger, 2000)

Planning	Concept Development	System-Level Design	Detail Design	Testing and Refinement	Production Ramp-Up
• Articulate market opportunity. • Define market segments. • Consider product platform and architecture. • Assess new strategies. • Identify production constraints. • Set supply chain strategy. • Research: Demonstrate available strategies. • Finance: Provide planning goals. • General management: Allocate Project resources.	• Collect customer needs. • Identify lead users. • Identify competitive products. • Investigate feasibility of product concepts. • Develop industrial design concepts. • Build and test experimental prototypes. • Estimate cost. • Assess production feasibility. •Finance: Facilitate economic analysis. • Legal: Investigate patent issues.	• Develop plan for product options and extended product. • Generate alternative product architectures. • Define major sub-systems and interfaces. • Refine industrial design. • Identify suppliers for key components. • Perform make-buy analysis. • Define final assembly scheme. • Finance: Facilitate make-buy analysis. • Service: Identify service issues.	• Develop marketing plan. • Define part geometry. • Choose materials. • Assign tolerances. • Complete industrial design control documentation. • Define piece-part production processes. • Design tooling. • Define quality assurance processes. • Begin procurement of long-lead tooling.	• Develop promotion and launch materials. • Facilitate field testing. • Reliability testing. • Life testing. • Perform testing. • Obtain regulatory approvals. • Implement design changes. • Facilitate supplier ramp-up. • Refine fabrication and assembly processes. • Train work force. • Refine quality assurance processes. • Sales: Develop sales plan.	•Place early production with key customers. • Evaluate early production output. • Begin operation of entire production system.

APPENDIX V

Frequency of Use and Importance of New Product Development Activities (Mahajan and Wind, 1992)

ACTIVITY	FREQUENCY OF USE	CRITICAL IMPORTANCE
New product idea generation	30	19
New product concept generation	43	40
Detailed market study for concept testing	4	14
Detailed market study for market identification, positioning and strategy	31	34
Business/financial analysis	70	55
Product development	79	71
Customer test of products	52	48
Pre-market volume forecast using prototype	20	9
Market test/trial sell	22	20
Market launch planning	54	41

APPENDIX VI

Reported New Product Introduction Time Reductions (Griffin, 1997)

PRODUCT	COMPANY	CYCLE TIMES	
		PREVIOUS	NOW
Hybrid Corn	Pioneer Hi-Bred	96	72
Construction Equipment	Deere & Co.	84	50
Helios (medical imaging)	General Electric	84	48
Viper	Polaroid	72	36
Cars	Chrysler	60	36
9900 Copier	Honda	60	36
Trucks	Xerox	60	36
DeskJet printers	Hewlett-Packard	54	22
Personal Computer	IBM	48	14
Thermostat	Honeywell	48	10
Air-powered Grinder	NCR	44	22
FX-3500 Copier	Ingersol Rand	40	15
Phone-Switchers	Fuji-Xerox	38	29
Electronic Pager	AT&T	36	18
Electric Clutch Break	Motorola	36	18
Communications Gear	Warner	36	9
Machining Gear	Codex	34	16
Machining Center	Cincinnati Milacron	30	12
Pampers Phases	Procter & Gamble	27	12
Leisure Lantern	Coleman	24	12
Cordless Phone	AT&T	24	12

Typical "Success-Cases" with Short Time-to-Market (Trygg, 1993)

PRODUCT	COMPANY	CYCLE TIMES (months)	
		PREVIOUS	NOW
Switching System	ABB	48	10
Phone	AT&T	24	12
Airplane	British Aerospace	36	18
Personal Computer	Digital Equipment	30	12
Engine	General Motors	84	48
Telephone system	Goldstar	18	9
Thermostat	Honeywell	48	12
Printer	Hewlett-Packard	54	22
Personal computer	IBM	48	12
Mobile-phone	Motorola	36	7
Truck	Navistar	60	30
Clutch-brake	Warner Electric	36	9
Copier	Xerox	60	24

APPENDIX VII

Summary of Research of NPD Cycle Time

Author & Publication Year	Type of Study	Industry Studied[50]	Unit of Analysis	Sample Size	Statistical Technique	Subject Area
Bayus (1994)	[redacted]					Investigated whether or not it was appropriate for cycle time to be shortened
Calantone and Di Benedetto (2000)	Empirical	Automobile	Firm	50	Correlation	
Crawford (1992)	Conceptual	Not stated	Not stated	None	Discussion	
Gupta et al (1992)	Empirical	Technology	Firm	46	Conjoint Analysis	
Millson et al (1992)	Empirical	Technology	Individual [51]	42[52]	Not Stated	Developed a hierarchy of approaches for reducing time
Brown and Eisenhardt (1995)	Conceptual	Not Stated	Not Stated	None	Discussion	[redacted]
Carmel (1995)	[redacted]					Described techniques for reducing NPD cycle time. Looked at the effects of various factors on time. Italics indicate studies that used samples of 35 or fewer cases to draw inferences concerning practices and effects on time
Cordero (1991)	Conceptual	Not stated	Not stated	None	Discussion	
Gupta and Wilemon (1990)	Empirical	[redacted]		38	[redacted]	
Lynn et al (1999)	Empirical	High-Tech[53]	Firm	341	Factor Analysis and Correlation	
Karagozoglu and Brown (1993)	Empirical	Computer equipment[54]	Firm	50[55]	None	
Kessler and Chakrabarti (1999)	Empirical	Scientific materials[56]	Project	86	Regression	

[50] All industries studied are different types of the Manufacturing industry and that are employ Advanced Manufacturing Technology.
[51] Unit of analysis is based on an assumption since group comprised of managers from a university-sponsored seminar and R&D directors
[52] One group comprised of 30 new product development managers and other group comprised of 12 R&D directors
[53] Other industries include electrical and electronic machines and supplies, transportation and transportation equipment, machinery, energy and instrumentation.
[54] Other industries include office equipment, communication equipment, electronic components and accessories, medical instruments and supplies, and computer-related services.
[55] The original sample, 50, was reduced to 31 because only 35 had NPD managers and were willing. Four were omitted as they did not meet the requirements
[56] Other industries include consumer and confectionary goods, chemical and chemical products, and industrial products and equipments.

Authors and Date of Publication	Type of Study	Industry Studied[57]	Unit of Analysis	Sample Size	Statistical Technique	Subject Area
McDonough and Barczak (1992) *McDonough and Barczak (1991)*	Empirical	Technology	Project	30 32	Multiple Regression	
McDonough (1993)	Empirical	High-Tech	Project	124[58]	Split Sample Analysis, Correlation	
Murmann (1994)	[redacted]					
Njissen et al (1994)	Empirical	Electronics[59]	Firm	263	Correlation	
Rabino and Wright (1993)	Conceptual	High-Tech	Not stated	None	Discussion	
Roseneau (1988)	Conceptual	Not stated	Not stated	None	Discussion	
Rusinko (1999)	Empirical	Metals[60]	Project	828	Regression	
Smith and Reinerstein (1992)	Conceptual	Not Stated	Not Stated	None	Discussion	
Trygg (1993)	Empirical	Machinery and metal working	Business Unit	283	None	
Cooper and Kleinschmidt (1994) Cooper and Kleinschmidt (1993)	Empirical	Chemical	Project	103	Pearson Correlation, ANOVA, t-test	Statistically correlated factors that improve the "timeliness" of a product development project
Chryssochoidis and Wong (2000)	Case research[61]	Medical Equipment and Supplies[62]	Firm	30	Regression	Examined the mediating effects of timeliness of NPD between product technology customization and overall success product

[57] All industries studied are different types of the Manufacturing industry and that are employ Advanced Manufacturing Technology.
[58] The sample consists of 32 questionnaires and 92 interviews.
[59] Other industries include metals and materials, chemicals, and pharmaceuticals.
[60] Other industries include fabricated and primary metals, machinery, electric and electronic equipment, transportation equipment, and instrumentation.
[61] The case research study followed a three-phase non-probability sampling procedure and multiple data collection methods.
[62] Other industries include mining machinery equipment, telephone communications and television, oil-field machinery, and earth-moving machinery

Authors and Date of Publication	Type of Study	Industry Studied[63]	Unit of Analysis	Sample Size	Statistical Technique	Subject Area
Emmanuelides (1993)	Conceptual	Not Stated	Not Stated	None	Discussion	Uses a multi-disciplinary approach to explore NPD process and the relationship between various factors and NPD performance
Griffin (1997)	Empirical	Chemical[64]	Project	343	ANOVA	Developed time variables for properly measuring stages of the NPD process
Terwiesch and Loch (1999)	Empirical	Electronics	Project	140	Regression	Confirm the effectiveness of overlapping development activities (a key component of CE) for reducing product development cycle time
Thomke and Fujimoto (2000)	[redacted]					
Duffy and Salvendy (1999)	Empirical	Electronic	Firm	822	Descriptive stats	Looked at the relationship between company performance and staff perceptions to see impact of CE on time
Zirger and Hartley (2000)	Conceptual	Not Stated	Not Stated	None	Discussion	Explained the intermediate processes that exist in the relationship between acceleration techniques and time

[63] All industries studied are different types of the Manufacturing industry and that are employ Advanced Manufacturing Technology.
[64] Other industries include electro-mechanical durables, consumer package goods, medical devices, and telecommunications services.

APPENDIX VIII

Principles of Concurrent Engineering

Linton et al. (1991) derive the following underlying first principles for CE:

1. CE's ideal model is a collaborative multi-discipline product development team that has the unity of purpose, integrated perception, and unified reasoning ability."

2. Competitive products depend upon focusing the knowledge and unique perspectives of progressively more specialized engineering disciplines upon all product development decisions."

3. More balanced interdisciplinary product trade-offs will be required to recognize, define and meet global market demands.

4. A collaborative, team oriented infrastructure within and among all activities of product development is far superior to any review-based sequential or non-team approach.

5. All activities within a product development process must be considered one integrated enterprise – not independent activities that are considered the exclusive domain of particular disciplines.

6. Authority among the members of a collaborative, multi-discipline product development team must always be equally shared.

7. A substantial competitive advantage is realized by a specific class of tools and technologies that provide all members of development teams complete visibility of evolving designs, support to identify and resolve conflicts, and the ability to equally influence decisions.

8. The effectiveness of product development teams is limited by the extent to which each team and team member is provided complete, continuous, and unambiguous visibility of the development enterprise as it evolves.

9. To implement CE, the executive standards by which management success is measured and accordingly career success is achieved must reflect CE principles.

10. Discipline management must collaborate to define balanced, market responsive product development team goals, empower team members to make trade-offs, share responsibility in measuring team, not individual, performance towards these goals, and foster a unity of purpose within each team and among teams.

11. Continuous improvement of product development practices is essential to compete successfully in a global market.

APPENDIX IX

Non-Monetary Recognition Systems (Kunkel, 1997)

Public Recognition

- Product Development team award dinners and cremonies
- Patent awards dinners
- "Hall of Fame" plaque presentations
- Recognition through video spots or the company newsletter
- Election to internal scientific societies
- "Nobel Prize" awards
- Quality awards
- "Product Manager of the Year" awards

Prizes, Plaques, etc.

- Plaques, insribed with a patent application
- A lucite cube containing a miniature product
- Desk name plates inscribed with awards and honours
- Coffee mugs and other identification paraphernalia for product names

Time Off

- Time allocated to work on "pet" projects
- Extra vacation for overtime worked
- Time off to attend a trade show or scientific convention

APPENDIX X

Conventional Project Management versus CE Project Management (Reinertsen, 1992)

Conventional Project Management

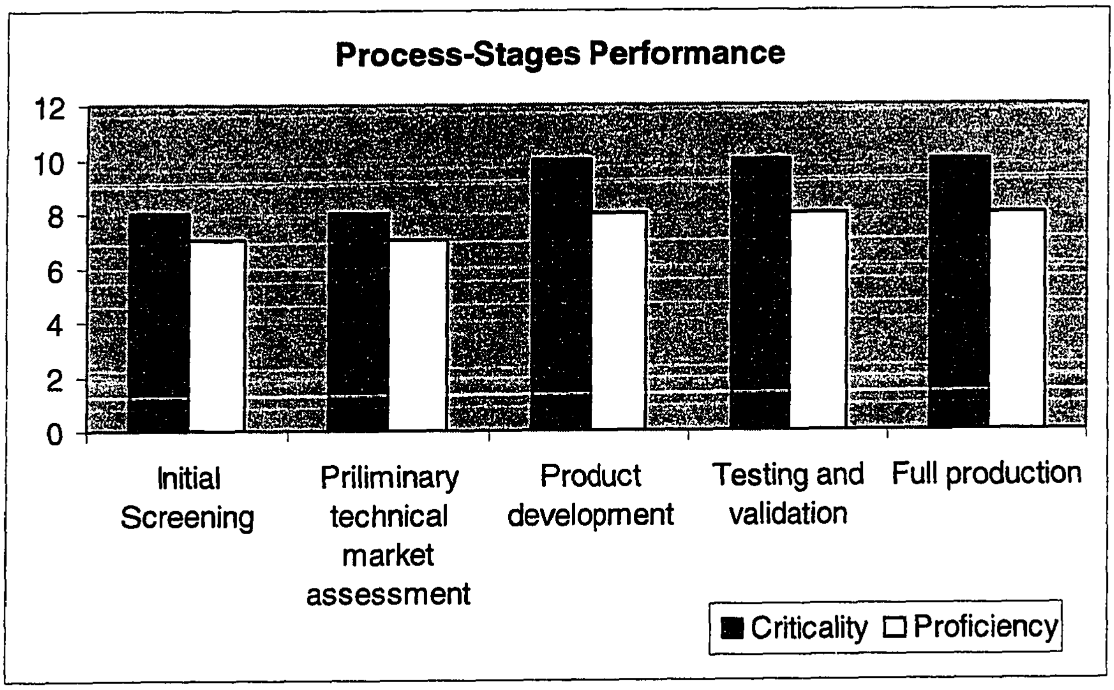
ACTIVITIES	TIME (WEEKS)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Planning	■	■	■												
Engineering Design				■	■	■									
Bill of Materials							■	■							
Procurement									■	■	■				
Production												■	■	■	
Ship to Customer															■

Concurrent Engineering

ACTIVITIES	TIME (WEEKS)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Planning	■	■	■												
Engineering Design		■	■	■											
Bill of Materials			■	■	■										
Procurement				■	■	■									
Production						■	■	■							
Ship to Customer									■						

APPENDIX XI

Criticality vs Proficiency of Significant NPD Stages (Poolton and Barclay, 2000)



APPENDIX XII

Use of Customer Involvemnt versus NPD Phases (Karagozoglu and Brown , 1997)

COMBINATION OF NPD PHASES	NO. OF COMPANIES	%
Technical and Commercial Feasibility	6	33
Idea Generation, technical commerical feasibility testing	5	27
Idea Generation	3	17
Idea Generation, technical commercial feasibility testing, prototype development	2	11
Technical commercial feasibility testing, prototype development	1	6
Product R&D	1	6

APPENDIX XIII

Strengths and Weaknesses of the Five Organizational Forms (Smith and Reinertsen, 1998; and Ulrich and Eppinger, 2000)

	FUNCTIONAL	LIGHTWEIGHT	BALANCED	HEAVYWEIGHT	PROJECT
STRENGTHS	Technical coherence and consistency across projects. Individuals do what they know best. Fosters development of deep specialization and expertise.	Identifies resource and schedule issues. Functional management remains in control. Each project has a focal person such as a single project manager who has control over only coordination and administration of project. Maintains development of specialization and expertise.	Allows strong functions with strong projects. Flexibility to move people and have dedication. Develops negotiation skills.	Fosters task overlapping and provides integration and speed benefits of the project organization. Members grasp project drivers. Fits with dedicated staffing and co-location. Some of the specialization of a functional organization is retained.	Concentration on one project. Focus on the customer. Easy to co-locate. Resources optimally allocated within the project team. Technical and market trade-offs can be evaluated quickly.
WEAKNESSES	Reinforces sequential development. Weak grasp of project drivers. Weak commitment to project. Coordination among different functional groups slow and bureaucratic.	"Team" lacks authority and has the illusion of great strength. Frustrating for the "leader". Requires more managers and administrators than the functional organization.	Questions about "who is my boss" Power struggles Individuals don't get clear guidance	Hard to find suitable leaders. Project can drift from other projects. Flux projects end. Requires more managers and administrators than the functional organization.	Projects are linked weakly. Hard at end to reintegrate. Little flexibility to move people. Individuals may have difficulty maintaining cutting-edge functional capabilities.

APPENDIX XIV

Questionnaire

1. Number of employees:

2. Types of products your firm provides:

3. To what extent, on a scale from 1 to 7, interactions take place amongst different departments (such as Design, Manufacturing and Marketing) during the process of product development, where 1 is "no interactions at all" and 7 is "extreme interactions". (*Please click on the box beside the appropriate number*).

Not interactions at all | Extreme interactions

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7

4. Please indicate whether or not phases of the New Product Development process were overlapped for the project.

☐ YES ☐ NO

5. In your opinion, how important are the following Concurrent Engineering (CE) Practices for reducing the time needed for the overall development of a new product, on a scale from 1 to 5. (*Click on a box from 1 to 5, where 1 is "not at all important" and 5 is "extremely important" in the box. Place "NS" anywhere on the scale if you are not sure about a particular practice.*)

CE PRACTICES	SCALE
People Practices	Not important at all — Extremely important
Co-location Locating personnel from different departments in close proximity to one another to breakdown functional barriers, and increase contact and bonds.	1☐ 2☐ 3☐ 4☐ 5☐
Cross-Functional Teams Members from different departments who collaborate during the NPD process in order to share product, process and design decisions.	1☐ 2☐ 3☐ 4☐ 5☐
Team Development Investing in education, training, and experience, in order to assure the depth and quality of the skills, and the capabilities of team members.	1☐ 2☐ 3☐ 4☐ 5☐
Team Leadership Degree to which teams are autonomous enough to make their own decisions without too much interference from the functional managers.	1☐ 2☐ 3☐ 4☐ 5☐
Reward and Recognition Team-based rewards (e.g. skill-based pay plans, team bonus systems, or profit sharing). Non-monetary rewards. Linking rewards to goals.	1☐ 2☐ 3☐ 4☐ 5☐

Process Practices	Not important at all — Extremely important
Customer/Supplier Integration Compliments cross-functional teams by including their representation as part of the team.	1☐ 2☐ 3☐ 4☐ 5☐
Formal NPD procedures Formalized framework to translate information into action – formal picture of the generic steps the firm goes through when developing the new product.	1☐ 2☐ 3☐ 4☐ 5☐
Formal Team Briefings All members are required to meet with one another in person and management may be present.	1☐ 2☐ 3☐ 4☐ 5☐
Organizational Redesign Redesigning better coordination mechanisms, a team structure approach, management support, functional roles and hierarchy, and reward systems.	1☐ 2☐ 3☐ 4☐ 5☐
Project Management Project specification, project budget assessment, technical risk assessment, project planning, and financial risk assessment	1☐ 2☐ 3☐ 4☐ 5☐
Tools and Techniques	
Computers/Networks Essential for automation and simultaneity of activities of the NPD process. Provide common databases for communication and sharing information.	1☐ 2☐ 3☐ 4☐ 5☐
Computer Aided Design Design software and hardware that uses interactive computer graphics to transfer design specifications and parameters with less probabilities of error.	1☐ 2☐ 3☐ 4☐ 5☐
Computer Aided Manufacturing Links with CAD and automated prototype manufacturing to plan for the manufacturing of the product and the actual control of production processes.	1☐ 2☐ 3☐ 4☐ 5☐
Simulation A descriptive technique that involves developing a model of a process and experimenting on the model to evaluate it under various conditions.	1☐ 2☐ 3☐ 4☐ 5☐
Formal Methods	
Design of Experiments Obtaining the optimal settings of a process or characteristic of a product design in order to determine which factors need additional study.	1☐ 2☐ 3☐ 4☐ 5☐
Design for Manufacturability Integration of design and development into one common activity to overcome the difficulty of translating needs into production design feasibilities.	1☐ 2☐ 3☐ 4☐ 5☐
Failure Mode and Effects Analysis Resolves potential problems – ranks all failure ways for a component with a risk priority number, suggests corrective action, and calculates improvement.	1☐ 2☐ 3☐ 4☐ 5☐
Quality Function Deployment A systematic focus on customer requirements to establish the importance of product attributes, and transform them into technical requirements.	1☐ 2☐ 3☐ 4☐ 5☐

<u>FOR THE FOLLOWING QUESTIONS PLEASE THINK OF A PRODUCT INTRODUCED WITHIN THE LAST 6 MONTHS TO A YEAR THAT WAS SUCCESSFULLY MARKETED BY YOUR FIRM.</u>

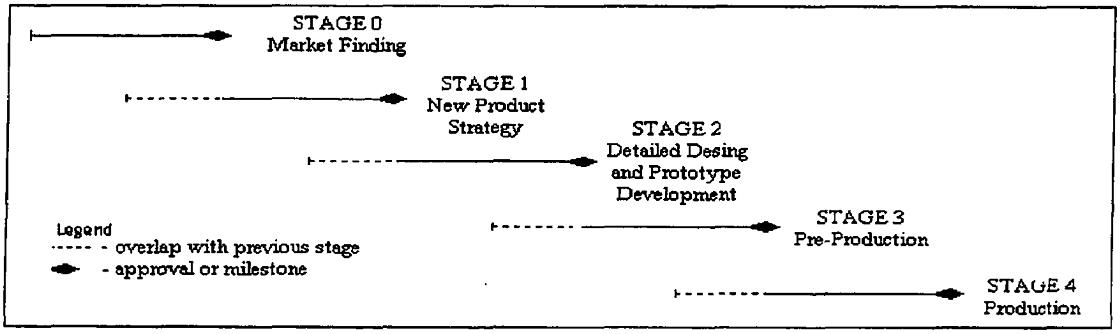
6. Was this product:
   - ☐ Entirely new to your firm.
   - ☐ Significantly modified/improved over a previous/existing product of your firm.
   - ☐ A minor modification to a previous/existing product of your firm.

7. To what extent, on a scale from 1 to 5, were the following Concurrent Engineering (CE) Practices used in the overall development of the product? (For an explanation of the practices, please see the table in question 5.) *(Click on a box on the scale from 1 to 5, where 1 is "not used at all" and 5 is "used extensively". Place "NS" anywhere on the scale if you are not sure about a particular practice.)*

CE PRACTICES	SCALE				
People Practices	Not used at all				Extensively used
Co-location	☐1	☐2	☐3	☐4	☐5
Cross-Functional Teams	☐1	☐2	☐3	☐4	☐5
Team Development	☐1	☐2	☐3	☐4	☐5
Team Leadership	☐1	☐2	☐3	☐4	☐5
Reward and Recognition	☐1	☐2	☐3	☐4	☐5
Process Practices					
Customer/Supplier Integration	☐1	☐2	☐3	☐4	☐5
Formal NPD procedures	☐1	☐2	☐3	☐4	☐5
Formal Team Briefings	☐1	☐2	☐3	☐4	☐5
Organizational Redesign	☐1	☐2	☐3	☐4	☐5
Project Management	☐1	☐2	☐3	☐4	☐5
Tools and Techniques					
Computers/Networks	☐1	☐2	☐3	☐4	☐5
Computer Aided Design	☐1	☐2	☐3	☐4	☐5
Computer Aided Manufacturing	☐1	☐2	☐3	☐4	☐5
Simulation	☐1	☐2	☐3	☐4	☐5
Formal Methods					
Design of Experiments	☐1	☐2	☐3	☐4	☐5
Design for Manufacturability	☐1	☐2	☐3	☐4	☐5
Failure Mode and Effects Analysis	☐1	☐2	☐3	☐4	☐5
Quality Function Deployment	☐1	☐2	☐3	☐4	☐5

BELOW IS AN EXPLANATION FOR THE QUESTION THAT FOLLOWS.

Many firms follow a process of steps when developing new products. For the purposes of this study the process is shown:



When measuring the time needed for the process, three measures of time (beginning with different stages) are considered.

1. **Time-to-Market**: includes Stage 0 (Market Finding) to Stage 4 (Production).
2. **Concept-to-Customer**: includes Stage 1 (New Product Strategy) to Stage 4.
3. **Development Time**: includes stage 2 (Detailed Design & Prototype Development) to Stage 4.

8. Please estimate the amount of **TIME-TO-MARKET** reduction that was achieved as a result of the use of CE practices for the development of the product you have been thinking of. (Click on the box above the percentages of time reduced.)

☐	☐	☐	☐	☐	☐	☐
0-5%	6-10%	11-20%	21-30%	31-40%	41-50%	>50%

9. Please estimate the amount of **CONCEPT-TO-CUSTOMER TIME** reduction that was achieved as a result of the use of CE practices for the development of the product you have been thinking of.

☐	☐	☐	☐	☐	☐	☐
0-5%	6-10%	11-20%	21-30%	31-40%	41-50%	>50%

10. Please estimate the amount of **DEVELOPMENT TIME** reduction achieved as a result of the use of CE practices for the development of the product you have been thinking of.

☐	☐	☐	☐	☐	☐	☐
0-5%	6-10%	11-20%	21-30%	31-40%	41-50%	>50%

11. To what extent, did the following practices actually reduce the time (Time-to-Market) needed for the development of the product? (*Click on box beside a number from 1 to 5, where 1 is "did not reduce time at all" and 5 is "extensively reduced time". Place "NU" anywhere on the scale, if a particular practice was not used during the project.*)

CE PRACTICES	SCALE				
People Practices	Did not reduce time at all				Extensively reduced time
Co-location	☐1	☐2	☐3	☐4	☐5
Cross-Functional Teams	☐1	☐2	☐3	☐4	☐5
Team Development	☐1	☐2	☐3	☐4	☐5
Team Leadership	☐1	☐2	☐3	☐4	☐5
Reward and Recognition	☐1	☐2	☐3	☐4	☐5
Process Practices					
Customer/Supplier Integration	☐1	☐2	☐3	☐4	☐5
Formal NPD procedures	☐1	☐2	☐3	☐4	☐5
Formal Team Briefings	☐1	☐2	☐3	☐4	☐5
Organizational Redesign	☐1	☐2	☐3	☐4	☐5
Project Management	☐1	☐2	☐3	☐4	☐5
Tools and Techniques					
Computers/Networks	☐1	☐2	☐3	☐4	☐5
Computer Aided Design	☐1	☐2	☐3	☐4	☐5
Computer Aided Manufacturing	☐1	☐2	☐3	☐4	☐5
Simulation	☐1	☐2	☐3	☐4	☐5
Formal Methods					
Design of Experiments	☐1	☐2	☐3	☐4	☐5
Design for Manufacturability	☐1	☐2	☐3	☐4	☐5
Failure Mode and Effects Analysis	☐1	☐2	☐3	☐4	☐5
Quality Function Deployment	☐1	☐2	☐3	☐4	☐5

12. In the space below, please indicate any other practices you think important for reducing New Product Development Cycle Time.

In case you would like to receive the summary results of the study, please provide the following information below (or attach your business card)

Name: Phone:
Position:
Address: mail:

THANK YOU KINDLY FOR YOUR TIME AND EFFORTS IN COMPLETING THIS QUESTIONNAIRE.

APPENDIX XV

List of Companies

COMPANY	PRIMARY INDUSTRY	ALTERNATE INDUSTRIES
Absopulse Electronics Ltd.	Electronics Parts and Components	Aircraft and Aircraft Parts Telecommunication Equipment
Advantech Inc.	Telecommunication Equipment	N/A
Amphenol Canada Corp.	Aircraft and Aircraft Parts	Telecommunication Equipment Computer Services
Apollo Microwaves Ltd.	Telecommunication Equipment	N/A
Arminius Telecom Inc.	Electronic Parts and Components	Other Chemical Products
Audio Products International Corp.	Record Player, Radio and Television Receiver	N/A
Baan Canada Inc.	Computer Services	N/A
Brownsburg Electronik Inc.	Electrical Transformer	Lighting Fixture Electronic Parts and Components Electrical Generating and Transmission Equipment and Supplies, Wholesale
Bryston Ltd.	Electronic Parts and Components	N/A
Comptec International Ltd.	Aircraft and Aircraft Parts	N/A
Coretec Inc.	Electronic Parts and Components	Telecommunication Equipment Other Communication and Electronic Equipment Computer Services
Corning Frequency Control	Electronic Parts and Components	Aircraft and Aircraft Parts
CVDS Inc.	Aircraft and Aircraft Parts	Electrical Switchgear and Protective Equipment
DALSA Inc.	Electronic Parts and Components	Electronic Computing and Peripheral Equipment
Edac Inc.	Electronic Parts and Components	N/A
Electronic Craftsmen	Electrical Transformer	Aircraft and Aircraft Parts
Esmond Manufacturing Inc.	Other Electrical Products	N/A
Filtran Microcircuits Inc.	Electronic Parts and Components	Telecommunication Equipment
Graphico Precision Division of Firan Technology Group	Electronic Parts and Components	N/A
ITL Circuits	Electronic Parts and Components	Custom Coating of Metal Products
Leitch Technology International Inc.	Record Player, Radio and Television Receiver	N/A
LogicVision Inc.	Computer Services	Computer and Related Machinery Equipment and Packaged Software

Magma Design Automation Inc.	Computer Services	N/A
Matrox Electronic Systems Ltd.	Electronic Computing and Peripheral Equipment	N/A
McNeill Electronics Ltd.	Electronic Parts and Components	N/A
Micralyne	Computer Services	Electronic Parts and Components
Miranda Technologies	Communication and Electronic Equipment	Electronic Parts and Components
Mitec Telcom Inc.	Communication and Electronic Equipment	Aircraft and Aircraft Parts
Mitel Corporation	Electronic Parts and Components	Telecommunication Equipment
Mosaid Technologies Inc.	Electronic Parts and Components	N/A
MPB Technologies Inc.	Communication and Electronic Equipment Industries	Indicating, Recording and Controlling Instruments
Navowave Remec Inc.	Telecommunication Equipment	Electronic Parts and Components
Noreast Electronics	Electronics Parts and Components	N/A
Nortel	Telecommunication Industry	N/A
Novatronics Inc.	Other Instruments and Related Products	Aircraft and Aircraft Parts Other Electrical Industrial Equipment
PC World Division of Circuit World Corp.	Electronic Parts and Components	N/A
PerkinElmer Optoelecronics	Electronic Parts and Components	Aircraft and Aircraft Parts Communication and Electronic Equipment
Pivotal Power	Electronics Parts and Components	Aircraft and Aircraft Parts Boat Building and Repair Industry
PMC-Sierra Inc.	Electronic Parts and Components	N/A
Pocatec Ltd.	Railroad Rolling Stock Industry	N/A
Primetech Electronics Inc.	Electronic Parts and Components	Computer Services Offices of Engineers
Pylon Electronics	Indicating, Recording and Controlling Instruments	N/A
Pylon Electronics Inc.	Indicating, Recording and Controlling Instruments	N/A
SAE Power Company	Electrical Switchgear and Protective Equipment	N/A
SDL Optics Inc.	Electronic Parts and Components	N/A
SiGe Semiconductor Inc.	Electronic Parts and Components	Computer Services
Sparton Electronics	Other Communication and Electronic Equipment	Lighting Fixture Telecommunication Equipment

Spectrum Signal Processing Inc.	Computer Services	Telecommunication Equipment Communication and Electronic Equipment Instruments and Related Products Electronic Machinery, Equipment and Supplies (Except Computer Equipment)
StrataFLEX Corporation	Electronic Parts and Components	N/A
Thomas & Betts Ltd.	Non-Current Carrying Wiring Devices	N/A
Trundra Semicondutor Corporation	Electronic Computing and Peripheral Equipment	Electronic Parts and Components Computer Services
Tundra Semiconductor Corp.	Electronic Computing and Peripheral Equipment	Electronic Parts and Components Computer Services
Visteon Automotive Systems	Electronic Parts and Components	N/A
WECO Electrical Connectors Inc.	Electronic Parts and Components	Other Metal Fabricating
Widecom Group Inc.	Communication and Electronic Equipment Industries	Other Office, Store and Business Machine Industries

APPENDIX XVI

Consent Form

I ______________________________(please print name), read the following:

The *purpose of this consent form* is to ensure that I understand:

- The purpose of the research I am contributing to
- How I became involved in this study
- My rights to participate or withdraw from this study
- Purpose of the research I am contributing to

The *purpose of this study* is to examine the extent to which Concurrent Engineering practices reduces New Product Development cycle time measured in terms of Time-to-Market, Concept-to-Customer, and Development Time in Canadian firms that produce Electronic Parts and Components. The results will be incorporated into a framework, which describes the Concurrent Engineering practices that reduce New Product Development Cycle times, which consist of different stages of the New Product Development Process.

I have been *invited to participate* in the research process for a Master of Business Administration thesis in the Eric Sprott School of Business at Carleton University. (Name of primary contact) (and/or) (position of primary contact), has identified me as the person with the most knowledge for participating in this research as I was either a Project Team Leader, R&D Manager, or someone responsible for a New Product Development project using Concurrent Engineering.

I will be asked to respond to a questionnaire or about Concurrent Engineering and its practices, New Product Development Cycle time, and differing amounts of product newness. The questionnaire will take approximately 25 minutes to complete.

Regarding the risks of this study, it is in the researcher's opinion there are no potential physical, emotional, financial, or social risks associated with this process. The economic risks may be changes to my compensation benefits should anyone in my firm become aware of the information I provide on the company's performance and competition issues with counterpart firms. The responses I give on the practices used by my firm to yield better performance results could hurt my firm if confidentiality is not guaranteed. The other risk I might face is the psychological impact of feeling compelled to participate, because my supervisor selected me.

I am promised anonymity and confidentiality. All responses given to the researcher will be reviewed only by the researcher and will be accessed only by the researcher. Questionnaires will be returned to the researcher's home where only the researcher has access to the mail, in a separate Self-Addressed Stamped Envelope showing no signs of the respondent. All information recorded will be locked up in a filing cabinet in a locked office. Only aggregate data gathered from all participants will be published in the thesis. At the study's end, all data will be destroyed.

My *voluntary participation* will be greatly appreciated for the completion of this study. I am, however, in no way obligated to take part in this study regardless of having been selected by someone within my organization. No penalty will be held against me should I voluntarily choose not to participate.

For further information on this project I may contact:

I understand the above description of the study and the conditions of my participation. Please check one of the following two conditions indicating your participation status.

☐ **I AGREE** to participate in the research.
(Please sign below)

Participant's Name (Please Print)	Signature of Participant
Researcher's Signature	Date

☐ **I DO NOT AGREE** to participate in the research.
(Please return form using self-addressed stamped envelope)

The researcher agrees to comply with the Tri-Council Policy Statement "Ethical Conduct for Research Involving Humans".

REQUEST FOR RESULTS ☐ YES ☐ NO

APPENDIX XVII

Pre-Notice Letter

Eric Sprott School of Business
710 Dunton Tower, 1125 Colonel By Drive
Ottawa, Ontario

January 23, 2002

Randa Saryeddine
Street Name
Ottawa, Ontario POSTAL CODE

A few days from now you will receive in the mail a request to fill out a brief questionnaire for a research project being conducted as part of the thesis requirements of the Master of Business Administration program at Carleton University.

It concerns Concurrent Engineering (CE) practices that are used in projects of firms producing Electronic Parts and Component in order to reduce the cycle time needed for New Product Development (NPD) of both Radical and Incremental Innovations.

I am writing in advance because it has been found that many people like to know ahead of time that they will be contacted to take part in a study should they consent to being a participant. The study is an important one that will help organizations in fast-paced industries identify which CE practices are most effective in reducing NPD cycle time for different types of innovation according to the perceptions of R&D Managers or Project Team Leaders who use these practices on a regular basis.

I would also like to specify that after having spoken with (person's name), (position of person), you were selected as the person most suitable for responding to the questionnaire, since you have been responsible for an NPD project that involved the use of Concurrent Engineering. Of course, as a result anonymity is no longer possible in this situation since you have been identified as a possible participant. Confidentiality and anonymity of the questionnaire you complete, however, is guaranteed.

Attached to this pre-notice letter is a consent form that explains your rights as a participant and confirms your willingness to take part in this study. Please note that you are free to withdraw from this study now or at any other point later on without any penalty held against you. Your participation is and always is absolutely voluntary.

Thank you for your time and consideration. It is only with the generous help of people like you that my research can be successful.

Randa Saryeddine
encl.

APPENDIX XVIII

Cover Letter

Eric Sprott School of Business
710 Dunton Tower, 1125 Colonel By Drive
Ottawa, Ontario

January 23, 2002

Randa Saryeddine
Street Name
Ottawa, Ontario POSTAL CODE

Dear (name of person or position of person),

You might recall from the pre-notice letter sent to you a couple of days ago that I am presently conducting a survey on Concurrent Engineering practices and their ability to reduce New Product Development cycle time for both Incremental and Radical Innovation. The specific issues that will be addressed include:

- What CE practices are used in Canadian Electronic Manufacturing organizations?
- To what extent do these practices reduce NPD Cycle Time, measured in terms of Time-to-Market, Concept-to-Customer, and Development Time?
- What gap exists, if any, between the actual usage of the CE practices and the perceived usefulness of the CE tools as seen by the Project Team Leaders or R&D Managers?

As mentioned in the previous letter, this research will form part of my Master degree of Business Administration at Carleton University.

Since your organization has been identified as using Concurrent Engineering in order to provide Electronic Components, I would ask you to please complete the enclosed survey and return it either via fax or mail. You will also have an opportunity to provide your input as well as request a copy of a report outlining the results of the survey.

Results of individual surveys are confidential and will not be disclosed to any outside parties.

Thank you for your time and input.

Sincerely,
Randa Saryeddine
encl.

APPENDIX XIX

Thank you Postcard

Thank You!

Two weeks ago, you were sent a survey regarding Concurrent Engineering Practices that reduce New Product Development Cycle Time for Incremental and Radical Innovation.

The time you have taken to complete the questionnaire is greatly appreciated.

If you have not already sent your questionnaire and require a duplicate sent to you please indicate this in the box below, as well as a fax number or mailing address for which the questionnaire may be sent.

☐ I request another questionnaire.

Mailing Address ____________________

Fax Number ____________________

____

☐ I no longer wish to participate.