**THE TRANSFER AND TRANSFORMATION OF TACIT KNOWLEDGE IN NEW
PRODUCT DEVELOPMENT: A CASE STUDY**

By

Julia Fulton, B. Comm.

**A Thesis submitted to
the Faculty of Graduate Studies and Research
In partial fulfillment of the requirements for the degree of**

Masters of Business Administration

**Eric Sprott School of Business
Carleton University
Ottawa, Ontario
2002**

© Copyright Julia Fulton, 2002

National Library
of Canada

Acquisitions and
Bibliographic Services

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale
du Canada

Acquisitions et
services bibliographiques

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence

Our file Notre référence

The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-79750-3

Canada

The undersigned recommend to
The Faculty of Graduate Studies and Research
acceptance of the thesis

THE TRANSFER AND TRANSFORMATION OF
TACIT KNOWLEDGE IN NEW PRODUCT DEVELOPMENT:
A CASE STUDY

submitted by JULIA FULTON, B. COM.
in partial fulfillment of the requirements for
the degree of Master of Business Administration

Director, Sprott School of Business

Thesis Supervisor

CARLETON UNIVERSITY
Friday, September 20, 2002

Abstract

Successful companies are characterized by their ability to consistently create “new knowledge,” quickly disseminate it, and embody it into new products. Much of this new knowledge is derived from, and is an amalgamation of tacit knowledge residing in individuals’ minds. For development of this new knowledge, tacit knowledge must be transferred and transformed from one individual to others. In typical new product development (NPD) settings this process occurs frequently within and between teams.

Tacit is described as that which is understood without being openly expressed. Since tacit knowledge resides in our minds and is personal and context specific, it is often difficult to articulate or transfer. Hence, one of the complexities in using tacit knowledge in NPD lies in the difficulty of transferring and transforming it among individuals and teams.

Research has shown that tacit knowledge is a valuable resource for product innovation. However more understanding is needed on how it may be transferred and transformed more effectively. The primary goal of this thesis is to explore the transfer and transformation of tacit knowledge primarily in the context of NPD, to gain insights on how this process may be more effectively carried out and, finally, to make overall recommendations on how tacit knowledge may be leveraged to improve NPD.

Several areas have been examined: the types of tacit knowledge relevant to NPD, their differential roles in the process, an examination of the processes that accomplish the transfer and transformation of tacit knowledge, the associated difficulties of these processes, and the factors and conditions that enable these processes. These areas were examined in three local high-tech companies engaged in NPD. Qualitative research techniques were used to conduct the analysis.

This research concludes with a knowledge management framework that can be used as a conceptual tool for understanding what critical tacit knowledge related processes need to be facilitated and supported to improve NPD.

Acknowledgments

I would like to express my profound gratitude to my research supervisor, Professor Shibu Pal, for his teaching and mentoring, tremendous insight, patience, and generosity with his time. A good professor is rich in knowledge and insight, evokes interesting debate and thought, and always has time for their students, Professor Pal has all of these qualities. The knowledge and lessons learned that he has imparted on me are priceless. For this, I am deeply grateful.

I would also like to thank my examination committee members, Professor Uma Kumar and Professor George Haines, for their insightful input, and supportive presence.

A special thanks goes to Jean Blair, who has supported me from the moment that I submitted my application to the School of Business. Her spirit, smile, and welcoming nature have been very meaningful to me.

To my friends who have always had an ear for my complaints and a voice to cheer me on, also deserve thanks, Lori Mason, Marilyn Fevrier, Su Soloway, Jackie Anawati, Sally Fletcher, Bharat and Manjari Maheshwari, and Aareni Uruthirapathy.

Special thanks also goes to my sisters, Debra and Stephanie Fulton, who both showed me an excellent example of what a good student is, and who always supported me, cheered me on, and offered helpful suggestions along the way.

I am grateful to my parents, Mike and Joy Fulton, for their financial support, love and encouragement. My parents always reinforced the idea from the early years on that a solid education is something that can never be taken away from you. I have always remembered this, and in difficult moments, I stayed true and steadfast to these words.

Finally, I want to thank my husband Raj Kapoor. His love, support, guidance, extremely helpful insights, and wonderful humor and patience were remarkable and also paramount to my completion of this thesis. For this, I dedicate this thesis to Raj.

TABLE OF CONTENTS

ACCEPTANCE SHEET	
ABSTRACT	
ACKNOWLEDGMENTS	
TABLE OF CONTENTS	
LIST OF TABLES	
LIST OF FIGURES	
LIST OF APPENDICES	

CHAPTER 1: INTRODUCTION.....	1
1.1 OVERVIEW.....	1
1.2 THESIS OUTLINE.....	5
CHAPTER 2: LITERATURE REVIEW.....	7
2.1 KNOWLEDGE	7
2.1.1 <i>Definition of Knowledge</i>	7
2.1.2 <i>Perspectives on Knowledge</i>	8
2.1.3 <i>Definition of Tacit knowledge</i>	9
2.2 TACIT KNOWLEDGE LITERATURE.....	12
2.2.1 <i>Tacit Knowledge Literature - Social Sciences</i>	12
2.2.2 <i>Tacit Knowledge Literature - Management</i>	12
2.2.3 <i>Managing Knowledge</i>	14
2.2.4 <i>Creating a Context for Successfully Sharing and Transferring Tacit Knowledge</i>	15
2.2.5 <i>Transferring Tacit Knowledge Through the Externalization Process</i>	16
2.2.6 <i>Transforming Tacit Knowledge Through a Knowledge Amplification Process</i>	18
2.3 THE NEW PRODUCT DEVELOPMENT PROCESS.....	23
2.3.1 <i>Definition and Description</i>	23
2.3.2 <i>Knowledge in New Product Development</i>	26
2.3.3 <i>Managing Tacit Knowledge in New Product Development</i>	27
2.3.4 <i>Descriptive Frameworks Modeling Tacit Knowledge Transfer and Transformation in New Product Development</i>	29
2.4 FACTORS THAT ENABLE THE SHARING, TRANSFER AND TRANSFORMATION OF TACIT KNOWLEDGE.....	30
2.4.1 <i>The Selection of NPD Team Members as an Enabler of Tacit Knowledge Transfer and Transformation</i>	30
2.4.2 <i>Factors Outside the Selection of Team Members as Enablers of The Tacit Knowledge Transfer and Transformation</i>	34

CHAPTER 3: THE CONCEPTUAL FRAMEWORK.....	39
3.1 TARGETED AREAS OF QUALITATIVE EXPLORATION.....	40
3.2 THE TEMPORAL NATURE OF TACIT KNOWLEDGE	41
3.2.1 <i>Types of Tacit Knowledge in New Product Development.....</i>	41
3.2.2 <i>The Temporal Nature of Tacit Knowledge.....</i>	42
3.3 TACIT KNOWLEDGE TRANSFER AND TRANSFORMATION IN NEW PRODUCT DEVELOPMENT.....	46
3.4 AN ANALYSIS OF TEAM FACTORS THAT ENABLE THE TRANSFER AND TRANSFORMATION OF TACIT KNOWLEDGE IN NPD.....	49
3.4.1 <i>The Selection of Team Members to Enable the Transfer and Transformation of Tacit Knowledge within NPD Teams.....</i>	50
3.4.2 <i>The Presence of Team Trust to Enable the Transfer and Transformation of Tacit Knowledge Within NPD Teams.....</i>	52
CHAPTER 4: RESEARCH METHODOLOGY.....	54
4.1 RESEARCH DESIGN.....	54
4.1.1 <i>Qualitative Research Design.....</i>	54
4.1.2 <i>Targeted Areas of Qualitative Exploration.....</i>	55
4.2 THE SAMPLE.....	56
4.2.1 <i>The Population.....</i>	56
4.2.2 <i>Sample Frame.....</i>	56
4.2.3 <i>Unit of Analysis.....</i>	57
4.2.4 <i>Case Study Approach.....</i>	57
4.2.5 <i>Evaluative Criteria of Qualitative Research and Case Research.....</i>	59
4.3 METHOD OF DATA COLLECTION.....	60
4.3.1 <i>Sampling Unit for the Interviews.....</i>	60
4.3.2 <i>Pre-test.....</i>	62
4.3.3 <i>Interview Protocol.....</i>	62
4.3.4 <i>In-depth Semi Structured Interviews.....</i>	63
4.4 DATA ANALYSIS.....	63
4.4.1 <i>Analysis of Interview Data.....</i>	64
4.5 INTERVIEW.....	64
4.5.1 <i>Interview Framework.....</i>	64
4.5.2 <i>Outline of Interview Questions.....</i>	65
CHAPTER 5: DATA ANALYSIS.....	67
5.1 DESCRIPTIVE DATA.....	68
5.1.1 <i>Descriptive Data - A Comparative Summary of Soft-Co, Comm-Co and Tel-Co.....</i>	68
5.1.2 <i>Small Software Company: Soft-Co.....</i>	70
5.1.3 <i>Medium Size Business Communications Company: Comm-Co.....</i>	77
5.1.4 <i>Multinational Telecommunications Company: Tel-Co.....</i>	84

5.2 EXPLORATION AND PROPOSITION EXAMINATION.....	93
5.2.1 <i>Proposition 1: The Temporal Nature of Tacit Knowledge</i>	93
5.2.2 <i>Exploring How the Transfer and Transformation of Tacit Knowledge Occur in NPD</i>	100
5.2.3 <i>Exploring Problems and Barriers to the Effective Transfer and Transformation of Tacit Knowledge</i>	107
5.2.3.1 <i>Tacit Knowledge Transfer and Transformation Problems Common to Soft-Co, Comm-Co and Tel-Co</i>	107
5.2.3.2 <i>Case Studies - Tacit Knowledge Transfer and Transformation Issues Specific to Each Case Study</i>	113
5.2.4 <i>Exploring Factors that Enable the Tacit Knowledge Transfer And Transformation Processes</i>	117
5.2.5 <i>Proposition 2a, b and 3: The Influence of Various Elements on the Tacit Knowledge Transfer and Transformation Processes within NPD Teams</i>	121
 CHAPTER 6: DISCUSSION OF THEMES, SIGNIFICANT FINDINGS, AND THE REVISED FRAMEWORK	132
6.1 DISCUSSION OF COMMON THEMES AND SIGNIFICANT FINDINGS.....	133
6.2 REVISED FRAMEWORK.....	140
6.2.1 <i>Revised Model 1: The Temporal Nature of Tacit Knowledge</i>	140
6.2.2 <i>Revised Model 2: The Transfer and Transformation of Tacit Knowledge in NPD</i>	144
6.3 KNOWLEDGE MANAGEMENT IMPLICATIONS.....	149
 CHAPTER 7: IMPLICATIONS AND LIMITATIONS OF THIS RESEARCH & SUGGESTIONS FOR FUTURE RESEARCH	151
7.1 IMPLICATIONS OF THE RESEARCH.....	151
7.1.1 Practical Implications.....	151
7.1.2 Academic Implications.....	152
7.2 LIMITATIONS OF THE RESEARCH.....	153
7.3 SUGGESTIONS FOR FUTURE RESEARCH.....	154
7.4 CONCLUSION.....	156
 REFERENCES	157

LIST OF TABLES

TABLE 1:	INTERVIEWEE DISCIPLINES.....	61
TABLE 2:	MISCELLANEOUS DATA, SOFT-CO, COMM-CO AND TEL-CO.....	68

LIST OF FIGURES

FIGURE 1:	KNOWLEDGE SPECTRUM.....	10
FIGURE 2:	NONAKA AND KONNO (1998) SECI - SPIRAL EVOLUTION OF KNOWLEDGE CONVERSION.....	17
FIGURE 3:	NUMATA AND TAURA (1996) D CYCLE - KNOWLEDGE AMPLIFICATION AMONG GROUPS.....	20
FIGURE 4:	STAINER AND NIXON (1997) THE NEW PRODUCT DEVELOPMENT PROCESS.....	24
FIGURE 5:	TEMPORAL NATURE OF TACIT KNOWLEDGE: A MODEL DEPICTING THE DIFFERENTIAL ROLES OF TACIT AND EXPLICIT KNOWLEDGE THROUGH NPD PHASES.....	45
FIGURE 6:	TEMPORAL NATURE OF TACIT KNOWLEDGE: A MODEL DEPICTING THE DIFFERENTIAL ROLES OF TACIT KNOWLEDGE TYPES THROUGH NPD PHASES.....	45
FIGURE 7:	A MODEL OF TACIT KNOWLEDGE TRANSFER AND TRANSFORMATION IN NPD.....	48
FIGURE 8:	NPD PROCESSES OF SOFT-CO, COMM-CO AND TEL-CO.....	70
FIGURE 9:	PROPOSED RELATIVE EMPHASIS ON TACIT AND EXPLICIT KNOWLEDGE THROUGH NPD PHASES.....	93
FIGURE 10:	PROPOSED RELATIVE EMPHASIS ON CONTEXTUAL AND TECHNICAL TACIT KNOWLEDGE THROUGH NPD PHASES.....	94
FIGURE 11:	PROPOSITION 2A - THE DEGREE OF HETEROGENEITY WITHIN THE CORE TEAM AND ITS EFFECT ON THE TEAM'S ABILITY TO TRANSFER AND TRANSFORM TACIT KNOWLEDGE.....	126
FIGURE 12:	PROPOSITION 2B - THE DEGREE OF SHARED MENTAL MODELS WITHIN CORE TEAM AND ITS EFFECT ON THE TEAM'S ABILITY TO TRANSFER AND TRANSFORM TACIT KNOWLEDGE.....	128
FIGURE 13:	PROPOSITION 3 - THE DEGREE OF TRUST AMONG AND BETWEEN NPD TEAMS AND THE EFFECT ON THE TEAM'S ABILITY TO TRANSFER AND TRANSFORM TACIT KNOWLEDGE.....	131
FIGURE 14:	THE TEMPORAL NATURE OF TACIT KNOWLEDGE REQUIREMENT & TEAM COMPOSITION.....	142
FIGURE 15:	LEVERAGING/EXPLOITING TACIT KNOWLEDGE IN NPD.....	145

LIST OF APPENDICES

APPENDIX A-1:	CONSENT FORM.....	163
APPENDIX A-2:	INTERVIEW QUESTIONS.....	165
APPENDIX B-1:	SOFT-CO ANALYSIS.....	188
APPENDIX B-2:	COMM-CO ANALYSIS.....	204
APPENDIX B-3:	TEL-CO ANALYSIS.....	216

Chapter 1: Introduction

1.1 Overview

Organizations depend on the accumulation and application of knowledge to create economic value. As competition increases, knowledge grows as a critical predictor of success. In the context of new product development (NPD) successful companies are characterized by their ability to consistently create “new knowledge,” quickly disseminate it, and embody it into new products (Nonaka, 1991).

Research suggests (Leonard and Sensiper, 1998; Nonaka and Konno, 1998) that much of this new knowledge is derived from, and is an amalgamation of tacit knowledge residing in individuals' minds. For the development of this new knowledge to occur tacit knowledge must be transferred and transformed from one individual to others, and in product innovation settings, from one team to the next.

This focus on the use of knowledge for competitive success has led to the present times being called the “knowledge era.” To remain competitive, knowledge, the intangible intellectual asset of an organization must also be managed (Amidon Rogers, 1996).

Tacit knowledge can be described as semiconscious and unconscious knowledge held in people's heads and bodies. “We know more than we can tell,” demonstrates the phenomenon that a large part of our human skill is tacit and remains unarticulated (Polanyi, 1966, p.4). Nonaka and Konno (1998) state that an individual's tacit knowledge is made up of knowledge about crafts and skills also referred to as know-how, and personal values, beliefs and mental models. On the opposite end of the knowledge spectrum from tacit knowledge, is explicit knowledge. Explicit

knowledge consists of words, numbers, data, manuals and the like. This form of knowledge can be easily transmitted in a systematic and formal representation or language. Tacit knowledge on the other hand is not so easy to transmit or articulate because of its semiconscious and unconscious composition and language.

Although the notion of tacit knowledge has been around for a long time, organizational theorists have only recently begun to examine its importance in organizations (Nelson and Winter, 1982; Nonaka and Takeuchi, 1995; Numata and Taura, 1996; Leonard and Sensiper, 1998; Nonaka and Konno, 1998). Nelson and Winter (1982) argue that much of the crucial know-how that sustains an organization resides mostly in the minds' of its organizational members. Research shows that greater levels of innovation can be achieved through harnessing collective tacit knowledge (Nonaka and Takeuchi, 1995; Leonard and Sensiper, 1998). Leonard and Sensiper (1998) explain that tacit knowledge is a valuable resource for innovation and that the creativity necessary for innovation derives not only from obvious and visible expertise but also from invisible reservoirs of experience. Nonaka and Takeuchi (1995) argue that innovations come about when organizational members share tacit knowledge and convert this into explicit forms such as a product, service or strategy.

Despite its competitive potential, research on tacit knowledge is scarce. Although some advances have been made, a lack of understanding still remains on how tacit knowledge can be more fully leveraged, exploited and harnessed to add greater value to organizational outputs.

Hedlund (1994) has suggested that tacit knowledge may be more effective and may provide greater value through the management of three important knowledge processes: transfer,

transformation and storage. He suggests that while “storage” conjures a static nature of the resource, acts of tacit knowledge transfer and transformation “dynamize” or mobilize the resource to useful purposes. Most of the tacit knowledge management research to date has focused on storage (also referred to as codification and storage, Zack 1999) (Nelson and Winter, 1982; Kogut and Zander, 1992; Zack, 1999); some research on the transformation of tacit knowledge has appeared (Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998); very little research attention has been placed on the transfer of tacit knowledge. Nonaka and Konno (1998) touch upon aspects of it in their explanation of knowledge creation (SECI Model). New research needs to cover all aspects of tacit knowledge management if companies are to leverage it, harness it, and receive greater value from it.

Not surprisingly, no empirical research seems to have been carried out on the transfer and transformation of tacit knowledge in new product development (NPD)--a process in which groups engage in creative thinking around the goal of distilling, combining and building upon individual members' knowledge.

The goal of this research was to better understand how the transfer and the transformation of tacit knowledge occur in an NPD environment, moreover, through a greater understanding of these two processes, how tacit knowledge can be more effectively leveraged in NPD. Our research goal targeted the investigation of several areas that pertain to the transfer and transformation of tacit knowledge: the types of tacit knowledge relevant in NPD, their differential roles in the process, an examination of the processes that accomplish the transfer and transformation of tacit knowledge, the associated difficulties of these processes, and the factors and conditions that enable these processes. These areas were qualitatively examined in three

high tech companies engaged in NPD. The research concludes with a knowledge management framework for NPD that outlines some of the critical tacit knowledge processes that need to be supported and facilitated to improve NPD.

The domain of new product development as the context in which this research is conducted is important to this research. This research focuses primarily on knowledge management within NPD because the development of a product represents the primary internal functions of many firms. One way that firms create competitive advantage is through the embodiment of new knowledge into new products. Hence, methods used to achieve the effective and efficient embodiment of tacit knowledge during NPD is an important part of a firm's competitive edge.

The NPD process is also argued to be predominantly driven by tacit knowledge-based activities that would benefit substantially from further insights into how tacit knowledge may be used more effectively. Eder (1998) suggests that much of the knowledge in NPD, such as knowledge about the strategic design approach and knowledge about tactics and methods for developing new products, are primarily tacit. Nonaka and Takeuchi (1995) say that recognizing and capturing tacit knowledge is critical to NPD. They argue that know-how, judgement and intuition (components of tacit knowledge) make up a critical component of information that needs to flow between members collaborating within NPD teams, hence this underscores the need for methods that transfer the tacit component of new product knowledge.

A recent study conducted by Ramesh and Tiwana (1999) also underlines the need for more understanding and effort to be placed on tacit knowledge management in NPD. Their research outlined two common problems that exist in the NPD processes of many firms: over reliance on

transmitting explicit rather than tacit design information, and the loss of tacit new product design and development knowledge throughout the NPD process. They argue that these problems ultimately affect cost, quality and time to market of new and next generation products.

Overall, the findings from this research provide a better understanding of how tacit knowledge may be more effectively leveraged to improve NPD. Two models introduced in the final framework explain what critical tacit knowledge processes should be focused on and supported. Although this framework is still to be empirically tested, it is our hope that the framework will facilitate a better understanding of how tacit knowledge is leveraged to improve NPD.

1.2 Thesis Outline

This thesis research is presented in seven chapters. Chapter One provides the introduction which outlines the reason for this research and the motivation behind it. Chapter Two is a review of previous literature useful for the understanding of this study. Particular attention is paid to the work of Nonaka and Konno (1998), Numata and Taura (1996), Leonard and Sensiper (1998) and Madhavan and Grover (1998). No empirical research has been found that describes the transfer and transformation of tacit knowledge in NPD. The findings from these researchers aided the development of the conceptual framework. The conceptual framework, Chapter Three, provides an outline of the relative emphasis on different tacit knowledge types at different phases and a description of how tacit knowledge may be transferred and transformed in NPD. Chapter Three also introduces several other factors that may enable these tacit knowledge transfer and transformation processes. Chapter Four describes the research methodology used. Chapter Five provides the aggregate findings of the data analysis, followed by Chapter Six in which the significant research findings are discussed, and the revised framework presented. Chapter Seven

provides the implications and the limitations of this research, and suggestions for future research.

Chapter Two: Literature Review

In this chapter four streams of literature are reviewed. First, literature on knowledge, tacit knowledge, managing knowledge and the new product development process is explored. Next, tacit knowledge and knowledge management literature is reviewed as it pertains to the context of NPD. Little research was found in this area, moreover, none was found that specifically addressed the processes of tacit knowledge transfer and transformation in NPD. The conceptual model outlined in Chapter Three attempts to describe how this process may occur by bringing together and re-conceptualizing some of the concepts that are described later in this chapter. The remaining section of this chapter summarizes the literature on factors that enable the knowledge sharing and tacit knowledge transfer and transformation process.

2.1 Knowledge

2.1.1 Definition of Knowledge

Davenport and Prusak (1998) define knowledge as a fluid mix of framed experiences, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. They suggest that it originates in the minds' of knowers and is embodied in documents, repositories, organizational routines, processes, practices and norms.

Knowledge is commonly distinguished from data and information. It is important to understand this distinction because it contributes to our understanding of how knowledge may be leveraged. Data represents observations and facts, which when taken out of context are not directly

meaningful. Information results from placing data within some meaningful context, often in the form of a message (Zack, 1999). "Information is a symbolic representation of reality, and such symbolic representation is often undertaken to enable decisions to be made" (Haines, 1978, p. 27). The distinction between knowledge and information is important, although knowledge is formed by information it is not an aggregate of information. Knowledge is that which we come to believe and value based on meaningfully organized information accumulated through experience, communication or inference (Bruner, 1973).

2.1.2 Perspectives on Knowledge

Cognitive scientists consider knowledge to be representations of the world that consist of a number of objects and events. They argue that knowledge is universal and that two cognitive systems should achieve the same representation of the same object or event. To the cognitivist, knowledge is explicit, capable of being encoded, stored and easy to transmit to others (Block, 1990). The cognitivist view on knowledge transmission was the predominant view for a long time. However, based on new insights in neurobiology, opinions about knowledge creation and transmission are changing. Maturana and Varela (1987) have suggested that cognition is a creative act of bringing forth the world. They believe that knowledge is not universal and that knowledge resides in our bodies and is closely tied to our senses and previous experiences. To the constructionist, some knowledge is *explicit*, but some is also *tacit*: highly personal, not easily expressed and therefore not easy to share with others (Maturana and Varela, 1987).

Many organizational theorists agree with the constructionist point of view, arguing that knowledge consists of both explicit and tacit dimensions (Polanyi, 1966; Lave and Wenger, 1991; Romer, 1995; Nonaka and Takeuchi, 1995).

Next we describe the concept of tacit knowledge, first by providing several definitions. Then a review of the literature on tacit knowledge use is presented as it pertains to the disciplines of social sciences and management, followed by the concept of knowledge management and the importance of managing tacit and explicit aspects of knowledge. Next, we review literature that introduces and expands on two tacit knowledge related concepts that we use in our conceptual model, namely the concepts of tacit knowledge externalization and amplification. We later combine and expand on these two concepts when we introduce our own conceptual model, the *Transfer and Transformation of Tacit Knowledge in NPD*.

2.1.3 Definition of Tacit Knowledge

Webster's dictionary (1993) describes "*tacit*" as that which is understood without being openly expressed. Polanyi (1966) was one of the early researchers to view all knowledge as having tacit dimensions. He described tacit knowledge as residing in people's heads and bodies. He argued that knowledge exists on a spectrum. At one end of the spectrum knowledge is tacit and at the other end, knowledge is explicit, see figure 1 below.

Figure 1: Knowledge Spectrum

Tacit Knowledge	Explicit Knowledge
<ul style="list-style-type: none"> ● Semiconscious ● Unconscious ● Knowledge in People's Heads ● Knowledge Rooted in People's Actions, Ideals, Values and Emotions 	<ul style="list-style-type: none"> ● Words ● Numbers ● Data ● Scientific Formulae ● Specifications ● Manuals

Tacit knowledge is typically developed through a process of trial and error encountered in practice, thus, intuition, experience, ground truth, judgement, values, assumptions, beliefs, and intelligence are examples of tacit knowledge that fall into this category (Tiwana, 2002).

Two examples of tacit knowledge, as noted above, are experience and intelligence, these are explained further through the following quotes, "as people's experience in their job increases, they begin to figure out shortcut solutions to problems they have never seen before. When they see a new situation, they match it to compare patterns that they are aware of. These tacit scripts guide our thinking and help us to avoid useless tracks that we might have followed earlier"; "when knowledge can be applied, acted on when and where needed, and brought to bear in present decisions, and when these lead to better performance or results, knowledge qualifies as intelligence" (Tiwana, 2002, p.45).

Zack (1999, p.46) describes tacit knowledge as “subconsciously understood and applied, difficult to articulate, developed from direct experience and action, and usually shared through highly interactive conversation, storytelling, and shared experience.” He argues that “explicit knowledge is more precisely and formally articulated than tacit knowledge, although removed from the original context of creation or use.”

Although tacit knowledge is on the opposite end of the spectrum from explicit knowledge, it is possible to convert some tacit knowledge to an explicit form. Converting tacit knowledge, also called *externalizing* tacit knowledge, is to translate tacit knowledge into comprehensible forms that can be understood by others. *Externalizing* tacit knowledge can be more easily achieved through methods (externalization tools) which we review later on in this chapter under the research of Nonaka and Konno (1998). Codifying tacit knowledge refers to the process of converting tacit knowledge into a written form. For example, an organizational routine which has been described in a procedural manual for the first time, has been “codified,” however, because of the nature in which organizational processes are developed, through the input of many individuals, complete understanding of the explicitly defined organizational process will most likely remain partly tacit.

Much knowledge remains tacit and is not extracted for various reasons. More commonly people are unaware of the tacit dimensions of their knowledge or find it difficult to articulate them. One type of tacit knowledge, typically very unconscious to individuals, is referred to by Spender (1996) as automatic knowledge. He describes it as embedded skill (embedded know-how), used to operate complex tools for various trades; another example would be instinctive driving skills that are acquired through years of driving experience.

2.2 Tacit Knowledge Literature

2.2.1 Tacit Knowledge Literature - Social Sciences

Although relatively new to management literature, the role and importance of tacit knowledge have been researched over the years in many other disciplines. For example, Imre (1985) and Holland (1985) view an examination of tacit knowledge as a potential bridge to unite the “objective theory” and “practice wisdom” that have dichotomized social work theory and practice. From an anthropological perspective, Heath (1984) suggests that much language is acquired implicitly—in a tacit manner over the course of a lifetime and not only through formal education. Cognitive psychologists (Reber, 1989) discussed the learning of grammar and probability, arguing that implicit learning is an unconscious process that leads to tacit knowledge.

2.2.2 Tacit Knowledge Literature - Management

Although initially conceived of at the individual level (Polanyi, 1962) some management scholars have focused on and described tacit knowledge as it exists in organizations (Nelson and Winter, 1982; Nonaka and Takeuchi, 1995; Nonaka and Konno, 1998) and in group settings (Numata and Taura, 1996; Leonard and Sensiper, 1998).

Nelson and Winter (1982) point out that much of an organization’s knowledge is tacit, in the minds’ of its organizational members. Nonaka and Takeuchi (1995) analyze the use of tacit knowledge in relation to the level of innovation in Japanese organizations. Their research findings suggest that tacit knowledge is a key source of organizational innovation that is important to sustainable company performance. Nonaka and Konno (1998) demonstrate an integral link between an organization’s ability to innovate and it’s ability to create new knowledge. Their

framework, modeling knowledge creation, shows that a large part of the knowledge creation process is the conversion of tacit to explicit knowledge, often achieved in part through what they call *externalization*. Our *Tacit Knowledge Transfer and Transformation* model uses the concept of tacit knowledge *externalization* to model how *tacit knowledge is transferred* between individuals and teams in NPD. Nonaka and Konno's concept of tacit knowledge externalization is an important part of our model, hence it is reviewed in greater depth later on in this chapter.

Numata and Taura (1996) introduce the concept of knowledge amplification in NPD. They insist that a modern firm's product is more reliant on the knowledge behind its design and development than the act of production itself. A prescriptive knowledge development model is suggested by Numata and Taura (1996) to aid in the level of innovative product development. Their prescriptive model is predicated on the concept of cooperative knowledge *amplification* in the product development process, described as a cooperative process of tacit and explicit knowledge sharing and transfer between engineers. Our model also incorporates Numata and Taura's concept of cooperative *knowledge amplification* to model *how tacit knowledge is transformed* within and between teams in the context of NPD. Numata and Taura's model of cooperative knowledge amplification is also an integral part of our model and is reviewed in greater detail later on in this chapter.

Leonard and Sensiper (1998) also provide additional insights into how tacit knowledge is amplified. They analyzed the role and importance of tacit knowledge in group innovation. They show how tacit knowledge is transformed through a process of trial and error encountered in practice. "In group activity, tacit knowledge has an important role in stimulating the 'requisite variety' of ideas and then in the convergence that permits focus on actionable next steps (p. 118).

"The above research suggests that organizations would benefit by consciously externalizing and using tacit knowledge in the creation of new products or services (Nonaka and Takeuchi, 1995; Numata and Taura, 1996). Other researchers have also argued that tacit knowledge is a critical component of that knowledge that needs to be shared and integrated if firms are to remain competitive (Drucker, 1991; Kogut and Zander, 1992). Although research tells us that it is strategically appropriate for all organizations to consciously externalize, share, transform and integrate their tacit knowledge (Saint-Onge, 1996), little understanding exists on how this may be effectively achieved. The management of these processes is the least understood aspect of knowledge management. Also, with respect to the task of successfully managing tacit knowledge comes the difficult challenge of each firm addressing which knowledge they should make explicit and which they should leave as tacit, a balance that can ultimately affect competitive performance (Zack, 1999). There is also some controversy around whether tacit knowledge can be managed (Zack, 1999) or whether it can only be enabled (Von Krogh, Ichijo and Nonaka, 2000). This also needs to be better understood.

2.2.3 Managing Knowledge

The American Productivity and Quality Center (2000) describe knowledge management as "the conscious strategy of putting both tacit and explicit knowledge into action by creating context, infrastructure, and learning cycles that enable people to find and use the collective knowledge of the enterprise."

Knapp (1998) describes knowledge management as "a set of processes for transferring intellectual capital to value--processes such as innovation and knowledge creation and knowledge acquisition, organization, application, sharing and replenishment."

Tiwana (2002) suggests that tacit knowledge is the most important type of knowledge to organizations and that knowledge management systems are needed to facilitate its sharing and integration. He additionally suggests that knowledge management systems should begin by leveraging the knowledge that already exists. This research focuses on leveraging tacit knowledge (a knowledge that already exists in organizations), by exploring how the transfer and transformation of it can be accomplished more effectively and efficiently within and between NPD teams.

With this in mind, we begin by reviewing several pieces of literature below that provide an understanding of the tacit knowledge transfer and transformation process. These areas of literature review introduced next, also build toward our conceptual framework outlined in Chapter Three.

2.2.4 Creating a Context for Successfully Sharing and Transferring Tacit Knowledge

Achieving a successful outcome of a given tacit knowledge transfer and transformation process depends greatly on whether a space for sharing knowledge exists. Although we review many factors that enable the sharing, transfer and transformation of tacit knowledge later on in this chapter, we felt that it was necessary to introduce and explain briefly the importance of creating a context for sharing knowledge because it sits at the heart of any tacit knowledge transfer and transformation success.

Von Krogh and Roos (1996) state that willingness to share knowledge and positive partner interactions are very important to the successful transfer of knowledge in a cooperative context. Stata (1989) states that the level of openness between two partners hinders or enables their

sharing process. He defines openness as the partners' willingness to put all the cards on the table, eliminate hidden agendas, make their motives, feelings and biases known, and invite other opinions and points of view. Badaracco (1991) states that sharing and openness is paramount to effective knowledge links because much of what the parties are trying to learn from each other, or create together can be difficult to communicate (it is often embedded in a firm's practices and culture, and it can only be learned through working relationships that are not hampered by constraints which impede sharing).

2.2.5 Transferring Tacit Knowledge through the Externalization Process

The concept of tacit knowledge *externalization* is used in this research to model how tacit knowledge is transferred between individuals collaborating for the purpose of developing a new product.

Externalization was first introduced by Nonaka and Konno (1998) in their knowledge creation model to describe one knowledge conversion pattern out of four that leads to the creation of new knowledge within organizations. Nonaka and Konno (1998, p. 42) say that knowledge creation is a spiraling process of interactions between explicit and tacit knowledge referred to as the knowledge spiral and that it is the exchange and transformation of these two knowledge types that leads to new knowledge. Externalization and the other elements of the SECI - Knowledge Creation Model are discussed briefly below.

Figure 2: SECI - Spiral Evolution of Knowledge Conversion, (Nonaka and Konno, 1998)

Quadrant 1,1: Socialization is referred to by Nonaka and Konno (1998, p. 43) as the sharing of tacit knowledge between individuals. Nonaka and Konno use the term socialization to emphasize that tacit knowledge is only exchanged through joint activities, and cannot occur through the exchange of explicit media. They emphasize the aspect of physical proximity to successfully share tacit knowledge.

Quadrant 1,2: *Externalization* is described by Nonaka and Konno as the explication of tacit knowledge through its translation into comprehensible forms. In a successful group process, the sum of all members' intentions and ideas converge and become integrated into one group mental map. They state that tacit knowledge is articulated through words, concepts, figurative expressions such as metaphors, analogies, narratives and storytelling. Leonard and Sensiper

(1998) also discuss externalization techniques; they support Nonaka and Konno's position and add tools such as prototyping and drawing to the externalizing repertoire within product innovation environments. They argue that for tacit knowledge to be externalized, individuals and groups must be comfortable with relying on physical demonstration or drawing not backed by logical, rational or hard data. Von Krogh, Ichijo and Nonaka (2000) argue that many business strategies do not account for the time it takes to express new ideas in a form that others can understand, and that many managers are not open to the playful use of language and metaphors necessary for externalizing tacit knowledge. Hedlund's (1994, p. 76) concept of articulation is similar to the externalization concept of Nonaka and Konno (1998). He emphasizes the importance of clear articulation for the expansion and improvement of tacit knowledge.

Quadrant 2,2: Combination is described by Nonaka and Konno as the conversion of explicit knowledge into more complex sets of explicit knowledge. They say that this phase relies on three processes: capturing, integrating new explicit knowledge and editing this knowledge to make it more readily usable.

Quadrant 2,1: Internalization is described by Nonaka and Konno as the conversion of explicit knowledge into the organization's tacit knowledge. At this phase explicit knowledge is embodied into action and practice. They say that the process of internalizing explicit knowledge actualizes concepts or methods about strategy, tactics, innovation or improvement.

2.2.6 Transforming Tacit Knowledge through a Knowledge Amplification Process

The concept of tacit *knowledge amplification* is used in this research to model how tacit knowledge is transformed between individuals and teams collaborating for the purpose of

developing a new product. *Amplification*, according to Webster's Dictionary (1993), is a process of expansion, clarification, improvement or a combination of all three. In our context, it can then refer to expansion, clarification, or improvement of either tacit or explicit knowledge. In all cases, the knowledge envelope expands as more tacit knowledge is input.

To understand how tacit knowledge may be transformed within an NPD team setting, we introduce the research of Numata and Taura (1996) and Leonard and Sensiper (1998). Numata and Taura (1996) use the concept of cooperative *knowledge amplification* in their prescriptive knowledge development model to emphasize the importance of, and the sharing and transfer of tacit design knowledge among product developers. Our *Tacit Knowledge Transfer and Transformation model* outlined in the conceptual framework uses Numata and Taura's (1996) D-Cycle of Knowledge Amplification and Formation Model, however unlike Numata and Taura's model, our conceptual model takes into account the cross functional nature of modern NPD practices—cross functional knowledge transfer that is required in successful collaborative product development from the areas of marketing, finance, planning, engineering and manufacturing (Song, Thieme and Xie, 1997), and also includes the critical *externalization* process (Nonaka and Konno, 1998) that is crucial to successful tacit knowledge transfer within and among NPD teams (Hedlund and Nonaka, 1993).

Numata and Taura's D Cycle of Knowledge Amplification and Formation (1996) described below, is outlined by a lettered sequence of activities (A - D) which describes the amplification process of individual specific tacit knowledge in an NPD team setting.

Figure 3: D Cycle - Knowledge Amplification Among Groups, (Numata and Taura, 1996)

The right hand side of the diagram is described by Numata and Taura (1996) as a process of tacit knowledge convergence. Stage A begins with individual tacit knowledge brought to the group in the form of original plans, drafts, etc., which satisfy the target goal. One draft or plan out of many is selected. In stage B, the ultimate plan is determined through repeat improvements of the primary draft. Within these repeat improvements individual tacit knowledge is constantly expanded, clarified or improved through the input of other tacit knowledge. Leonard and Sensiper (1998) describe this as a process of group divergence and then convergence. Stage C, describes actions which verify the feasibility of the primary plan or draft through the actual operation of it in

practice.

Numata and Taura (1996) argue that tacit knowledge belonging to an individual is not only amplified through experiments and simulations but also transferred from individuals with high levels of tacit knowledge. In NPD the amplified knowledge is often transferred between NPD teams through the transfer of the physical prototype and product specifications.

Numata and Taura (1996, p. 357) argue that the outcome of a group's convergence process is often influenced by the clarity and the strength of the group's objectives. They call this the "objective issue." "It is important to aim for the target with determination and a clear philosophy even if it seems impossible to achieve the goal in technical terms at the time."

For a deeper description of this process we summarize some of the research findings of Leonard and Sensiper (1998). Their arguments provide further insights into how tacit knowledge may be amplified within a team setting.

According to Leonard and Sensiper (1998) the tacit knowledge amplification process can be described as cycles of divergent thinking followed by convergent thinking. They suggest that these cycles of divergent and convergent thinking occur during all phases of product development, "managers need to manage both the expansion of thought that gives rise to potentially creative alternatives and the homing in on a viable option" (1998, p. 116). Tacit knowledge they say, has an important role in stimulating the variety of ideas, and then in the group convergence, that permits focus on actionable next steps. In working groups, individuals from different intellectual backgrounds draw on their pools of tacit as well as explicit knowledge to contribute. Leonard and

Sensiper (1998) argue that it is the tacit dimension of their knowledge base that make such individuals especially valuable contributors to group projects. If managers of the NPD process can manage diverse view points well, it fosters what is called "creative abrasion" or creative conflict, an optimum state into which conflicting view points can be channeled into new ideas.

Organizational researchers agree that the number of times this process of group divergence and convergence occurs during the tacit knowledge amplification process is influenced by a number of areas: the degree to which shared mental models exist between team members (Madhavan and Grover, 1998; Hedlund and Nonaka, 1993), the degree to which members have prior work experiences together (Madhavan and Grover, 1998), the degree of team heterogeneity and homogeneity (Leonard and Sensiper, 1998, Madhavan and Grover, 1998), the level of trust within the team (Madhavan and Grover, 1998) the nature of the problem to be solved and/or product being developed (Leonard and Sensiper, 1998) and the team member's abilities to solve problems, frame problems and their ability to predict and anticipate (Leonard and Sensiper, 1998).

Leonard and Sensiper (1998, p. 121) state that there are potentially three main ways in which the tacit knowledge of an individual is potentially exercised during the cycle of divergent and convergent thinking: problem solving, problem framing, and prediction and anticipation. We use problem solving, problem framing and prediction and anticipation to describe further the skills that can be used to achieve greater success within the amplification process.

The most common application of tacit knowledge to innovation and/or new product development is problem solving. "Experts in a particular area of product design and development can solve a problem more readily than novices because they have in mind a pattern born of

experience which they can use to quickly detect a solution.”

Problem framing is another application. The development of innovation and new technology often requires that developers re-frame a particular problem to provide insight and room into the real nature of a problem. For example, “consultants are familiar with the situation in which a client identifies a problem and sets out specifications for its solution, where as the real value may lie in reformulating the problem.”

The last way that tacit knowledge is potentially serviced in the face of product innovation is through prediction and anticipation skills. Skilled and experienced engineers in innovation often find them selves anticipating and predicting occurrences which are then subsequently explored. Leonard and Sensiper (1998) suggest that this kind of anticipation and reliance on inexplicable mental processes can be very important to product innovation. For example hunches, intuition and insights would fall into this category.

Next we review the literature that describes the NPD process, types of knowledge used in NPD, the importance of tacit knowledge to the NPD process and managing tacit knowledge in the NPD process.

2.3 The New Product Development Process

2.3.1 Definition and Description

Definition: Clark and Fujimoto (1991) defined product development as “a process by which an organization transforms data on market opportunities and technical possibilities into information assets for commercial production.”

Because each product development project has unique project demands, NPD systems are likely to differ across projects and across companies. Other researchers (Wind, 1988; Cooper and Kleinschmidt, 1986) have also pointed out that the same new product development model should not be applied to all companies. In general, larger technology companies typically have NPD processes in which principal tasks are defined and grouped into phases. For some smaller technology firms who have yet to define and describe their NPD process, identifying and segregating NPD tasks into phases can provide a framework for analyzing critical knowledge flows and needs.

Over the past decade more structured approaches for managing the NPD process have emerged. For example, Stainer and Nixon (1997) have proposed a seven-stage process for moving a new product from idea to product launch, see figure four below.

Figure 4: The New Product Development Process, (Stainer and Nixon, 1997)

Stainer and Nixon divide the process into a predetermined set of phases each consisting of a group of prescribed, related and often parallel activities. Their model also has gates which function as control check points which require that certain criteria be met before the project is allowed to proceed further.

In addition to the stage gate process several other methods for managing NPD have been used, such as phase review processes—sequential phases with designed inputs and outputs, product and cycle time excellence—facilitating the stage-gate system, quality function deployment—incremental improvement and information structure, and value proposition process—continuous learning and continuous cycling. Although these methods may vary with respect to procedures and integrative mechanisms, the early phases of many of these systems usually involve idea generation and a preliminary market and technical investigation prior to product design and development.

The first two phases, idea generation and product concept defines the way in which an organization proposes and selects concepts and how these concepts may converge to a specific product definition and design. Critical processes in this phase are those for identifying customer needs and matching these needs with technological capabilities to generate potential new product concepts. Identifying the correct customer needs is very much dependant on the solicitation of feedback from customers through marketing activities (Hise et al., 1990). The next two phases, design and development, are defined by working level activities which iron out the bare bones of the product design and produce a working prototype of the new product. The last two phases are defined by activities related to the verification and testing of the prototype. These activities are followed by volume production, commercialization and then sales.

Somewhere in the details of the tasks to be completed at each phase, lies a whole set of choices that the firm must make about the overall development process—how tasks and activities should be sequenced, how work should be organized, how product information and knowledge should be compiled and retained, how the effort should be led and managed, what milestones should be established, how management will interact with the project, and methods for problem solving and problem finding (Clark and Wheelwright, 1992).

2.3.2 Knowledge in New Product Development

Although NPD consists of a myriad of activities, some sequential, some parallel, it is the creation of new knowledge that can be viewed as the central theme of the new product development process. In NPD, knowledge is continuously created, transferred, combined, stored at all phases, and ultimately embodied in product and process designs (Clark and Fujimoto, 1991; Nonaka and Takeuchi, 1995). Below, we review the basic categories and types of knowledge that are used in NPD.

Effective product development requires involvement from diverse functional knowledge sets. Researchers (Dougherty and Heller, 1994; Nonaka and Takeuchi, 1995) have shown that NPD requires knowledge types and functional expertise from areas such as marketing, manufacturing, research and development, finance and planning.

Court (1997) has also identifies three general categories of knowledge that are used during the NPD process: *general knowledge*—knowledge that people apply without regard to any specific domain, *domain specific knowledge*—knowledge gained through study and experience within a specific domain and, *procedural knowledge*—knowledge gained from the experience of

undertaking a task within a domain.

A broader definition of *procedural design knowledge* is provided by Davenport and Prusak (1998). They describe it as experiential, including explicit aspects such as fundamental design concepts criteria, specifications, theoretical tools, practical considerations, and design instrumentalities as well as tacit aspects. Eder (1998) argues that most procedural knowledge in NPD is tacit based.

The concept of knowledge management in NPD, although still relatively new to the NPD world has been touched upon (Leonard and Sensiper, 1998; Madhavan and Grover, 1998; Ramesh and Tiwana, 1999). Research has suggested that some type of knowledge management structure and support is required to leverage knowledge types (explicit and tacit) to improve NPD.

2.3.3 Managing Tacit Knowledge in New Product Development

The idea of managing knowledge and or managing tacit knowledge in NPD is also still very new. Although Leonard and Sensiper (1998) introduce basic types of tacit knowledge that need to be managed in NPD, they provide little knowledge on how this can be effectively accomplished. Ramesh and Tiwana (1999) outline the consequences that new product developers experience when various elements of tacit knowledge management are ignored (lack of tacit knowledge codification and transfer in particular). These discussions are presented below.

Leonard and Sensiper (1998, p. 119) outline three types of tacit knowledge in NPD which they argue require management: overlapping specific, collective and guiding tacit. Some of these tacit knowledge types will be referred to in the data analysis chapter of this research.

Overlapping specific tacit knowledge is described as shared specific knowledge which is required for the completion of interdependent tasks. For example, an understanding of steps in a production process may constitute shared specific tacit knowledge.

Collective system tacit knowledge is described as knowledge which has been developed communally over time. “ It exists more or less in the heads of group members who have been socialized into a group” (1998, p. 121). This kind of collective tacit knowledge is described for being essential to how members of a firm communicate and by extension how they innovate.

Guiding tacit knowledge is described as knowledge which represents a deep understanding and purpose about something. It often takes the form of metaphors or guiding images. For example, the development of an innovative new product or service often lacks guidance, one method of developing the guiding tacit knowledge of the group is to have the group collectively develop logos, vision and mission statements.

Hence, a wide variety of NPD knowledge, much of it tacit based, makes the task of tacit knowledge sharing, transfer and transformation between team members particularly important. Despite the important role of managing tacit knowledge in NPD, no descriptive or prescriptive framework appears to exist on how tacit knowledge and its related processes can be managed and leveraged.

Ramesh and Tiwana (1999) outline two common NPD problems as a result of this deficiency; 1- over reliance on transmitting explicit rather than tacit design information, for example, (1999, p. 220) “during the design and development of a PDA, participants from the manufacturing

department might not realize that surface mount component chips cannot tolerate over a certain soldering temperature during the process of manufacturing. Though the hardware design group is well aware of this through their chip set specification literature, this knowledge was not shared with manufacturing.”; 2- The second common problem is the loss of tacit knowledge throughout the new product development process, for example, (1999, p. 221) ”the designers of the RF components assume that the designers of the computing processors are aware of the interference that the processor may cause within the communication components. This knowledge though obvious to the RF designers, is not commonly well understood by other team members. In absence of explicit requirements for the RF team, the processor designers ignore the issue.”

2.3.4 Descriptive Frameworks Modeling Tacit Knowledge Transfer and Transformation in NPD

No empirical research has been found that adequately describes the transfer, transformation and integration of tacit knowledge in NPD. Numata and Taura (1996) build a theoretical and integrative model of tacit knowledge in NPD based primarily on the concept of knowledge amplification. However, their model does not take into account a) the cross-functional nature of modern NPD practices, b) the critical externalization process suggested by Nonaka and Takeuchi (1995). Both of these inadequacies are addressed in the conceptual framework of this research outlined next in Chapter Three.

Next we review the literature that provides insight into how the tacit knowledge transfer and transformation process may be enabled in the context of NPD.

2.4 Factors that Enable the Sharing, Transfer and Transformation of Tacit Knowledge

Many factors can affect the sharing, transfer and transformation of tacit knowledge within NPD. For example, the organization's climate, the organization's design, the way incentive systems are created, the selection of team members, how the team is managed, how team members interact and communicate and so on.

Although all of these factors can influence the sharing, transfer and transformation of tacit knowledge, this research limits itself to the team as the unit of analysis in which the tacit knowledge transfer and transformation process is analyzed. The team's relationship with the organization and other external factors will be discussed briefly below to provide greater understanding, but are not variables that will be examined in this research. This research will examine factors related specifically to the selection of team members and the issue of trust as an enabler of tacit knowledge transfer and transformation within teams.

2.4.1 The Selection of NPD Team Members as an Enabler of Tacit Knowledge Transfer and Transformation

New product development teams are engaged in knowledge producing activity. "The individual brings to the situation his/her own repertoire of skills, knowledge, strategies which affect and are affected by the situation. This dynamic interaction of individual and context results in the cognitive performance of the team" (Patel, Kaufman, and Arocha 1995). The cognitive performance of the team will affect the success of the product. Moreover, how the team interacts and who interacts in the team will often be important NPD determinants (Madhavan and Grover, 1998).

Madhavan and Grover (1998) describe this as a process of converting the embedded tacit knowledge of individual team members and embodying it into the final product. They argue (1998, p. 2) that “the potential for new knowledge is embedded in the team and its interaction.” They describe embedded knowledge “as the potential knowledge resulting from the combination of the individual team member’s stores of tacit knowledge. They say that a cross functional team is brought together because its members have collective knowledge that cannot be held efficiently by any of its individual members.”

We borrow the terms embedded and embodied knowledge from Madhavan and Grover (1998) and use them to help describe the objectives of the tacit knowledge transfer and transformation process, *the objective of team management is the process of managing the transfer and transformation of tacit knowledge throughout NPD phases from embedded knowledge to embodied knowledge*. The degree to which certain variables are present will help with the successful outcome of this process.

In their research, Madhavan and Grover (1998) tested several variables which they believed would help to achieve the embodiment of tacit specific knowledge into the new product. We revisit some of the variables which they have tested and modify them slightly to fit our research. Literature is provided below to demonstrate the validity of these factors to enabling the tacit knowledge transfer and transformation process.

Developing Heterogeneous and Homogeneous Teams to Enable of the Tacit Knowledge Transfer and Transformation Process:

New ideas are rarely the undertaking of one individual but often spring from the interaction of

individuals with different knowledge sets (Simon, 1985). Apparently these differences stimulate the “requisite variety” of ideas that permits focus on a wide array of actionable next steps (Campbell, 1960). Leonard and Sensiper (1998, p. 116) say that “creative group activity is not confined to the initial phases of the overall innovation effort but in fact is essential to down stream activities such as launching a new product or improving after sales service to a customer” (Leonard and Sensiper, 1998, p. 116).

A team that is comprised of different knowledge sets is what is referred to in this research as heterogeneous team development. Leonard-Barton (1995) describes the process that often occurs within a team with different knowledge sets as the process of creative abrasion—described as the deliberate conflict of ideas. “Apparently hearing a different perspective challenges the mind set of those in the majority sufficiently that they will search beyond what initially appears to be an obvious solution.” (Leonard and Sensiper, 1998, p.118). Janis (1982) says that homogeneous (similar knowledge sets) can often be subject to what is called “group think,” a comfortable common view point leading to close mindedness and pressures toward uniformity.

While the differences in intellectual tacit knowledge sets provide a greater array of ideas, managing the “creative abrasion process” can be difficult. Leonard and Sensiper (1998) suggest that the process can be positive but that the team leader in charge should understand the nature of group conflict and know how to manage it. Manhavan and Grover (1998, p.3) argue that the outcome of the creative abrasion process can also be unsuccessful at times creating too much team divergence to achieve objectives. They suggest that the success of the process will depend largely on the capability of individual specialists to sustain a meaningful and synergistic conversation with one another. To enable a positive outcome of the “creative abrasion process”

they suggest that group members have what they call T-shaped skills, “Individuals with T shaped skills are described as being experts in a specific technical area who are also intimately acquainted with the potential systemic impact of their particular tasks on other tasks.”

Developing NPD Teams with Shared Mental Models or Shared Understanding to Enable the Tacit Knowledge Transfer and Transformation Process:

Shared mental models refer to similar, common memory bases of organizational experiences. Several researchers state that organizations are a network of inter-subjectively shared meanings, sustained by a common language and interpretive schema (Burrell and Morgan 1979; Daft and Weick, 1984; Walsh and Ungson, 1991). Hedlund and Nonaka (1993) argue that the availability of this common language is rich in symbolic imagery and metaphor which will facilitate the externalization and internalization of tacit knowledge.

Hutchins and Klausen (1996, p. 23) support the idea that shared prior knowledge becomes a resource to negotiate or construct a shared understanding of the situation in which the team members find themselves.

Building Trust in NPD Teams to Enable the Tacit Knowledge Transfer and Transformation Process:

Researchers (Zand, 1972; Krietner and Konicki, 1992) have supported the idea that trust among team members will have a significant influence on team performance. Our research refers to two types of trust: trust in team orientation and trust in team members' technical competence. Trust in team orientation is described by Madhavan and Grover (1998, p. 5) as, “team members have reciprocal faith in others' intentions and behavior to work toward team goals rather than toward narrow or individual goals or agendas.” Trust in team technical competence is described

by Madhavan and Grover (1998, p. 6) as, “the reciprocal faith team members have in one another to complete the tasks in their areas of expertise successfully.”

Zand (1981) says that this type of trust is critical to the success of cross functional or inter-organizational team performance. Hedlund and Nonaka (1993) say that lack of trust can be especially harmful to the process of tacit knowledge externalization and internalization.

2.4.2 Factors Outside the Selection of Team Members as Enablers of Tacit Knowledge Transfer and Transformation

Organizational Climate:

Effective knowledge creation puts particular demands on the way people relate to each other in a company. Constructive and helpful relations speed up the communication process, enable organization members to share personal knowledge and to discuss their ideas and concerns freely (Von Krogh, 1998).

Von Krogh (1998, p. 138) says that “organizational relationships range from high - care relationships (characterized by considerable mutual trust, active empathy, access to help, lenience in judgement and courage) to low care relationships (characterized by distrust, no empathy, little or no access to help, authoritative judgement, and cowardice). Depending on the extent to which care is present, the knowledge creation, transformation and transfer process in a company will differ considerably.” He comments that there are many ways to destroy care in a company. For example, establishing bureaucracy with clear job descriptions and sanctions to be expected when high performance targets are not met, weak job security and unjust behavior toward employees, such as firing people without giving adequate explanations, and tolerating injustices such as

allowing employees to steal ideas and present them as their own (Von Krogh, 1998, p.142). These are all likely to make people protect their knowledge base. Tacit knowledge transfer and transformation is a social process. The first step in knowledge transfer and transformation hinges on creating a space for individuals to share their personal beliefs about a situation with team members. If employees are protecting their knowledge base, the prospect of leveraging tacit knowledge becomes difficult.

Organizational Design:

Hedlund (1994) argues that effective knowledge management requires departures from the traditional hierarchical organization. He comments that the quality and quantity of dialogue are important determinants of the effectiveness of knowledge transfer and transformation and that quality and quantity are often negatively affected by inflexibility and tightly specified systems of knowledge found in hierarchical systems. Leonard and Sensiper (1998) remark on hierarchy in organizations, they say that hierarchies detract from the leverage otherwise gained through the use of tacit knowledge found at all levels in an organization, "hierarchies implicitly assume that wisdom accrues to those with the most impressive organizational titles" (Leonard and Sensiper, 1998, p. 126).

Nonaka and Konno (1998) stress open organizational designs and customer interfaces to encourage face to face interaction. They argue, physical separation and time renders tacit knowledge difficult to share and open organizational designs make casual face to face contact and knowledge sharing, transfer and transformation easy.

Incentive Systems:

Von Krogh (1998) says that management can encourage the transfer of tacit knowledge by creating incentive systems which encourage, enable and reward the disseminators of tacit knowledge. Team based incentives in NPD are one effective way of encouraging the sharing and transfer of tacit knowledge. Von Krogh suggests that teams can receive a reward based on their overall performance and that this reward should be split equally among all team members. This incentive will likely encourage individual participants to share personal knowledge in order to contribute to the overall performance of the team (Von Krogh, 1998).

How the Team is Managed:

Managing tacit knowledge is a challenge. Group participation and sharing of tacit knowledge can be severely inhibited through poor management style (Leonard and Sensiper, 1998) Leonard and Sensiper comment on several issues which must be continually and positively addressed by management if tacit knowledge is to be shared, transferred and transformed among individuals in team environments: the ongoing encouragement and respect for different thinking styles, encouraged experimentation, the understanding between intelligent failures and unnecessary mistakes and a high importance placed on assisting others, "in organizations where expertise is highly regarded, but assisting and/or mentoring others is not, rational people may be unlikely to surrender the power they gain from being an important knowledge source" (Leonard and Sensiper, 1998, p.126).

The Selection of Team Members:

Researchers have outlined several group factors that may hinder the transfer and transformation of tacit knowledge between group members. Leonard and Sensiper (1998) say

that inequality among group participants is a strong inhibitor to sharing tacit knowledge. Pelled (1996) says that group diversity based on highly visible differences (gender, race, age) leads to more emotion-based disagreements, whereas more subtle forms of diversity (educational background, work experience) are more likely to lead to intellectual disagreements. Pelled argues that tacit knowledge is not heard and valued as much in groups where group differences are readily observable.

Communication Mediums Used Between Team Members:

Distance, both physical separation and time makes tacit knowledge difficult to share. Realtime e-mail, teleconferencing and groupware are technologies which may be instrumental in sharing tacit knowledge where face to face interaction is not possible, however the bulk of tacit knowledge is generated and shared through body language and physical demonstration of skill (Nonaka and Takeuchi, 1995). Rich personal interaction, described as face to face, informal and frequent interactions among team members are said to enhance group cohesiveness and trust and promote the transfer and transformation of tacit knowledge (Moorman, Desphande and Zaltman, 1993; Nonaka and Konno, 1998).

Enabling the Tacit Knowledge Transfer and Transformation Process through Mentoring and Social Activities:

Knowledge is to a large part equated with powers and influence, and tacit knowledge shielding at higher levels is often common practice. Mentoring programs open up the organizational members' access to the expertise in the company and encourage employees to make their own expertise available as knowledge grows (Von Krogh, 1998).

Social events are likely to stimulate good reaction. Informal chats, organizational parties can all have a great effect on organizational relationships. Time can be allocated to explore the interest of fellow employees. This can greatly enhance the desire to share knowledge, and hence enable the tacit knowledge transfer and transformation process.

Chapter Three: The Conceptual Framework

Prior discussions in the literature review highlighted the theoretical and empirical validity of tacit knowledge and its importance to the NPD process. Recall that: tacit knowledge has been demonstrated as a valuable resource for product innovation (Leonard and Sensiper 1998; Nonaka and Konno, 1998); other researchers have also suggested that it is the largest type of knowledge used in the development of a new product that could potentially add much greater value through methods that focus on leveraging it (Leonard and Sensiper, 1998; Teece, 1998; Eder, 1998; Madhavan and Grover, 1998; Ramesh and Tiwana, 1999); other empirical research (Ramesh and Tiwana, 1999) has shown that repercussions exist when methods are not used to capture, transfer and store tacit knowledge during new and continuous product development (Ramesh and Tiwana, 1999).

The primary goal of this research was to examine the nature of tacit knowledge use and transfer and understand how it may be leveraged in NPD. Preliminary investigation into this research topic showed us that tacit knowledge can be potentially leveraged through efforts placed on several areas: tacit knowledge transfer, transformation, codification and storage (Hedlund, 1994; Zack, 1999). We narrowed our principal research focus to the exploration of tacit knowledge transfer and transformation. However, other aspects pertaining to how tacit knowledge may be leveraged in NPD are also explored.

We target several broad areas pertaining to the domain of tacit knowledge transfer and transformation. Some of these areas examine the nature of tacit knowledge transfer and transformation in NPD, and other areas examine how it may be enabled in the context of NPD.

All areas targeted are provided below under section 3.1 - *Targeted Areas of Qualitative Research*.

Several conceptual models, outlined later in this chapter, have also been developed for the purpose of broadening our understanding of some of these targeted areas. These conceptual models also helped in the development of the data collection instrument (interview questions). For some of these targeted research areas we also developed propositions.

3.1 Targeted Areas of Qualitative Exploration

1. Exploring the temporal nature of tacit knowledge. The temporal nature examines the relative emphasis on tacit and explicit knowledge, and the relative emphasis on different tacit knowledge types at different phases in NPD.
2. Exploring how the transfer and transformation of tacit knowledge occurs within and between teams during NPD. This process examines the senders and recipients of tacit knowledge transfer and transformation, and tacit knowledge externalization and amplification as mechanisms of tacit knowledge transfer and transformation.
3. Exploring the problems/obstacles associated with achieving the transfer and transformation of tacit knowledge and the problems/obstacles associated with leveraging tacit knowledge in general. Here we examine knowledge breakdowns¹ within the core team and between NPD teams, and examine the reasons for these breakdowns and whether they are due to insufficient tacit knowledge transfer or codification. We also explore other aspects of NPD failure and whether it is due to the insufficient transfer of tacit knowledge.
4. Exploring factors that encourage the transfer and transformation of tacit knowledge.
5. Examining team composition within NPD and its effect on the tacit knowledge transfer and transformation processes within the team.
6. Examining the degree of trust within teams and between teams in NPD and its effect on the tacit knowledge transfer and transformation processes.

1

Knowledge Breakdown - Knowledge breakdown was described as a situation where the context or contents of knowledge transfer, message, or information was misinterpreted.

For our exploration into the temporal nature of tacit knowledge (targeted area of qualitative exploration no.1) we developed two conceptual models, figures 5 and 6, called *The Temporal Nature of Tacit Knowledge in NPD*. Figure 5 and 6 respectively, outline what we believed to be the relative emphasis on tacit and explicit knowledge at different phases of NPD, and the relative emphasis on different tacit knowledge types at different phases of NPD.

For our exploration into when and how tacit knowledge is transferred and transformed in NPD (targeted area of qualitative exploration no. 2), we developed a conceptual model, figure 7, called *The Transfer and Transformation of Tacit Knowledge in NPD*. This model provides a simple description of how tacit knowledge may be effectively transferred and transformed in NPD.

3.2 The Temporal Nature of Tacit Knowledge

To begin our exploration on the temporal nature of tacit knowledge in NPD (no. 1- Qualitative Exploration) we present a brief description of tacit knowledge types used in NPD.

3.2.1 Types of Tacit Knowledge in NPD

New product development requires expertise (tacit knowledge) in many areas - marketing, technology, finance, manufacturing, legal, organization-specific R&D strategy and operational criteria and standards to name a few. It is useful to classify the different kinds of tacit knowledge that are brought to bear in the NPD process as that allows us to trace their source, examine patterns of use and understand knowledge limitations. With this in mind, the use of tacit knowledge in NPD is classified into two areas:

1. Contextual Tacit Knowledge
 - a. Contextual external: tacit knowledge pertaining to external organizational issues required in the development of a new product - knowledge about the customer, competition, the potential channels of distribution, standards and some knowledge about manufacturing if that operation is to be outsourced.
 - b. Contextual internal: tacit knowledge pertaining to internal organizational issues required in the development of a new product - knowledge about how the product should be planned and organized, financial project management knowledge, marketing knowledge required for internal and external marketing on the new product.
2. Technical Tacit Knowledge
 - a. Tacit knowledge about the technology and the construction of it - knowledge about the design, development, testing and verification and manufacturing of the product. This is the tacit know-how a scientist or an engineer would develop over the years of working with the technology and which is above and beyond the explicit descriptions of the technology found in scholarly literature and text books.

3.2.2 The Temporal Nature of Tacit Knowledge

The NPD literature has recognized the relative importance of different knowledge types used at various NPD phases, however, none directly applies to the observation in the tacit knowledge domain. This discussion will facilitate our understanding of tacit knowledge use in the various NPD phases.

Serve (1990) suggests that knowledge and expertise from the following functional areas are critical to NPD: marketing, finance, product planning, engineering, R&D and manufacturing (Serve, 1990). Song, Thieme and Xie (1998) point out that uncertainties such as changes in environments, competition, customer needs and government legislation lead to dependencies and cooperation between these functional areas during some phases. Other studies (Griffin, Abbie and Hauser, 1996; Gupta, Ashok, Raj and Wilemon, 1986) argue that collaborative input and development between R&D and marketing is an important factor in NPD success. Moreover, in Quality Management literature, the models built around Quality Function Deployment and House

of Quality also call for inputs from marketing and product and process engineering (see for example, Pyzdek, 1991, p.160).

Although it has been contested (Song and Parry, 1993), some scholars (Olson, Walker, Orville and Ruekert, 1995) also insist that under some conditions NPD activities may be performed more effectively and efficiently without cross functional involvement. Moenaert et al.(1995) also qualified the importance of cross functional knowledge at some phases but not at others. They observed greater successes with product development from teams that make use of cross functional knowledge (marketing, planning, R&D, finance and manufacturing) during the beginning and end phases (planning, conceptual development and commercialization) but not so much during the mid phases which are mainly design and development activities. They argue that it may be inefficient, ineffective and costly to include cross functional involvement from areas such as planning, marketing and finance during the product design and development Phases.

With this latter argument, we propose two conceptual models depicting the *Temporal Nature of Tacit Knowledge*. One model outlines the relative emphasis on tacit and explicit knowledge use at different phases of development. This model shows that we expect more tacit knowledge use during the initial phases of product development. The idea for the product is largely tacit (residing mostly in the mind's of individuals) and will remain mostly tacit until the specifications for the basic design (prototype) have been written. We expect more explicit knowledge use in the latter phases of development, manufacturing and marketing when explicitly defined plans are implemented.

The second model outlines the relative emphasis on tacit knowledge types through NPD phases. Extrapolating some of the suggestions of Moenaert (1995) for this model, we propose

that in the early and late phases of the product development cycle (i.e., idea generation, product concept development, commercialization and sales), technical tacit plays a relatively minor role. At these phases the process is governed mainly by *internal and external contextual tacit knowledge*. For example, we would expect marketing and planning functions to be the key source of expertise regarding product user needs, competition and channels of distribution. At the mid-phases, the role of *technical tacit knowledge* becomes more significant. Here, we would expect that R&D-engineering would be the primary sources of expertise required during the design and development of the technology. Requirements for technical expertise at the design, testing and validation phases remain substantial until the product is robust. Figure 5 depicts the expected relationship between tacit and explicit knowledge at each phase of NPD, and figure 6 depicts the expected relationship between contextual and technical tacit knowledge at each phase of NPD. The real practical value of the *Temporal Nature of Tacit Knowledge* models will come from future empirical research that correlates product success with the level and types of expertise (tacit knowledge) required at each phase of NPD.

Figure 5: Temporal Nature of Tacit Knowledge: A Model depicting the Differential Roles of Tacit and Explicit Knowledge through NPD Phases

Figure 6: Temporal Nature of Tacit Knowledge: A Model Depicting the Differential Roles of Tacit Knowledge Types through NPD Phases

P1: The temporal model proposes that the relative emphasis placed on the transfer of these different tacit knowledge types changes through different phases in the development of a new product, that is:

P1a: At the beginning to mid phases of new product development the need is more for the transfer of tacit knowledge. At the mid to end phases of new product development the need is more for the transfer of explicit knowledge.

With respect to tacit knowledge types at each phase:

P1b: At the beginning and end phases of new product development the need is more for the transfer of contextual tacit knowledge pertaining to internal and external organizational issues. At the mid phases of new product development the need is more for the transfer of technical tacit knowledge.

3.3 Tacit Knowledge Transfer and Transformation in New Product Development

As an introduction into the area of exploration on how the transfer and transformation of tacit knowledge occur in NPD (no. 2-Qualitative Exploration) we present a model (and discussion) outlining two concepts that describe how and when tacit knowledge transfer and transformation occur in NPD.

Product development is a team-based activity, yet tacit knowledge resides in individual heads. This implies that for the dispersed tacit knowledge to come together and be used in the process and influence the final product, it needs to be a) transferred and b) transformed. In this section we attempt to apply models of these processes to an NPD environment. This model builds on two notions, introduced earlier in the literature review: tacit knowledge externalization and amplification. Recall that externalization refers to the conversion of experiential subjective tacit knowledge into objective explicit knowledge and amplification refers to the process where explicit and tacit knowledge are clarified, expanded or improved through the input of tacit knowledge.

The effective transfer and transformation of tacit knowledge depend on the processes of tacit knowledge externalization and amplification. Prior discussions in the literature review highlight the necessity of the externalization process for the effective transfer of tacit knowledge (Nonaka and Konno, 1998; Hedlund, 1994). Recall that Nonaka and Konno (1998) include the process of externalization as a prerequisite to effectively translating tacit to explicit knowledge in their knowledge creation model. Hedlund (1994) also emphasizes the role of externalization in the expansion and improvement of tacit knowledge.

Prior discussions in the literature review (Numata and Taura, 1996) also highlight the necessity of the tacit knowledge amplification process in transforming tacit knowledge into the explicit target objective of the group. Leonard and Sensiper (1998) also argue that creative development can often only be accomplished through the input and influence of many individuals with different functional perspectives, each building upon and improving on each others' ideas (Leonard and Sensiper, 1998).

These two sub-processes, externalization and amplification appear to be parallel at times and occurring in small cycles throughout the NPD process. Researchers have discussed these two processes separately, as mechanisms for leveraging tacit knowledge (Nonaka and Konno, 1998; Numata and Taura; 1996).

In this model the processes of externalization and amplification are combined to offer a plausible explanation of how tacit knowledge might be transferred, transformed and integrated into the development of a new product. See figure 7, which depicts the processes of tacit knowledge transfer, transformation and integration into the final product through cyclical processes of tacit

knowledge externalization and amplification at each phase of NPD.

Figure 7: A Model of Tacit Knowledge Transfer and Transformation in NPD

The transfer of tacit knowledge occurs when one member of a team shares their tacit knowledge. Recall that the transfer of tacit knowledge is most successful when individuals use what this research has referred to as externalization tools (prototyping, drawing, storytelling, anecdotes, examples, brainstorming)—techniques that best enable the change of experiential subjective tacit into objective explicit knowledge (Nonaka and Konno, 1998). The transformation

process occurs when another group member takes the shared knowledge and expands or improves it. This transformation is then an amplification process. At all points in the product development process managers need to manage and promote conditions that enable both the externalization of tacit knowledge and the expansion of thought in the amplification process that gives rise to potentially creative alternatives that are needed to effectively and efficiently develop new products.

3.4 An Analysis of Team Factors that Enable the Transfer and Transformation of Tacit Knowledge in NPD

As an introduction into our area of exploration on the factors that enable the transfer and transformation of tacit knowledge in NPD (no. 4, 5, 6 -Qualitative Exploration), we introduce the following discussions and propositions: the presence of team heterogeneity/homogeneity, the presence of team shared mental models, the presence of team trust to enable the transfer and transformation of tacit knowledge in NPD.

Recall from the literature review, Patel, Kaufman and Arocha (1995) argue that the selection of team members will affect the performance of the team which will in turn affect the outcome of the new product.

Madhavan and Grover (1998) expand this idea, they argue that a team's ability to create "new knowledge" (recall that "new knowledge" is created from tacit knowledge) will affect the outcome of a new product. They additionally propose that a team's potential for creating new knowledge

within a group is the result of several factors: T-shaped skills², shared mental models, A-shaped skills of the team leaders³, trust between team members, information redundancy and rich person interaction. They suggest that the degree to which “new knowledge”—tacit knowledge, is created and integrated into a product is dependant upon the presence of these variables above.

In this research, we examine the effect of some these variables on the tacit knowledge transfer and transformation processes in the context of NPD. Specifically we have examined: the degree of core team heterogeneity and homogeneity, the degree of core team shared mental models, and the presence or lack of team trust within the core team and between other NPD teams, and analyze the effect of these variables on the core team’s ability to transfer and transform their tacit knowledge.

3.4.1 The Selection of Team Members to Enable the Transfer and Transformation of Tacit Knowledge within NPD Teams

In our proposition we argue that the degree of team heterogeneity in an NPD team will have a curvilinear relationship with the effectiveness with which the tacit knowledge externalization and amplification process of that team occurs. Team heterogeneity or cross functional team composition will stimulate tacit reservoirs within the team, which will especially facilitate better NPD team research, however some degree of similar understanding is also needed to facilitate tacit

2

T shaped skills - “Not only experts in specific technical areas but also intimately acquainted with the potential systemic impact of their particular tasks. On the one hand they have a deep knowledge of a discipline, on the other hand they also know how their discipline interacts with others.” (Madhavan and Grover, 1998, p. 3).

3

A shaped skills - “Some individuals embody technology fusion. Some people actually learn more than one discipline (although more then two is unlikely) and so have two disciplinary legs on which to stand.” (Leonard -Barton, 1995, p. 77). “Although rare such persons provide another mechanism for managing creative abrasion within teams.” (Madhavan and Grover, 1998, p. 4).

knowledge externalization and amplification as well. Hence, we argue that a balance of both is required for the overall effectiveness of tacit knowledge externalization and amplification with an NPD team. Prior discussions in the literature lend support for this argument (Leonard-Barton 1995; Simon 1985).

First recall, Leonard and Sensiper (1998) suggest that tacit reservoirs are stimulated more within heterogeneous groups. Simon (1985) also suggests that greater creativity and new ideas will spring from heterogeneous teams. However, other researchers (Madhavan and Grover, 1998) have also suggested that heterogeneous teams experience more conflict than homogenous teams, and the knowledge building process in NPD becomes more difficult to manage the greater the degree of heterogeneity within the team. They argue that some degree of shared understanding must be present between team members if the knowledge is to be efficiently and effectively externalized and amplified. Hypothesis No. 2a is derived from these arguments.

P 2a: The degree of heterogeneity among the team will have a curvilinear relationship (inverted U) with the effectiveness with which the team can externalize and amplify its tacit knowledge to achieve effective NPD.

Prior discussions in the literature lend support for the idea that the outcome of a team interaction is the construction of a shared understanding of the situation in which the team members find themselves. This research argues that the greater the degree to which there is a shared understanding between team members the greater the success with which tacit knowledge is externalized and amplified within the team. This argument is based predominantly on the research of Hedlund and Nonaka (1993) and Hutchins and Klausen (1996). Hutchins and Klausen (1996) say that during group integration, this shared prior knowledge becomes a resource to construct a shared understanding of a particular situation. Hedlund and Nonaka (1993) argue that

the articulation, internalization and reflection of tacit knowledge are facilitated by the availability of this common language that is rich in symbolic imagery and metaphor. Hypotheses No. 2b is derived from these arguments.

P2b: The degree to which mental models within the team are shared will have a positive relationship with the ease and effectiveness with which the team can externalize and amplify its tacit knowledge.

3.4.2 The Presence of Team Trust to Enable the Transfer and Transformation of Tacit Knowledge within NPD Teams

This research argues that the more trust there is between team members the greater the effectiveness with which tacit knowledge is externalized and amplified. Prior discussions in the literature review lend support for this hypothesis. Zand (1972) argues that trust between team members has a significant influence on team performance.

Two types of trust are examined in this research. Trust in team orientation and trust in team members' technical competence. Madhavan and Grover (1998, p. 5) describe trust in team orientation as "team members having reciprocal faith in others' intentions and behavior to work toward team goals rather than narrow, individual or functional goals or agendas." Hedlund and Nonaka (1993) say that the withholding of information due to a lack of trust can be harmful to the process of knowledge externalization, internalization and reflection.

The second type of trust examined in this research is trust in team members' technical competence. Madhavan and Grover (1998, p. 5) refer to this type of trust as "team members having reciprocal faith that other team members will complete the tasks in their area of expertise successfully either by involving themselves or other suitable persons." Moorman, Desphande and

Zaltman (1993) argue that technical competence can be observed readily in a group and that this type of observation can influence the sharing of tacit knowledge. Hypothesis No. 3 is derived from these arguments.

P3: Greater level of trust among team members will have a positive relationship with the effectiveness with which tacit knowledge is externalized and amplified within the team.

Elements of the hypotheses, discussions, and conceptual framework presented in this chapter form the basis of our interview questions which are provided in Appendix B.

Chapter Four: Research Methodology

In this chapter the design of the research is outlined. Because the topic of this research is still in its early stages of development, exploratory research methods (Van Maanen et al., 1982)⁴ in particular, qualitative methods were employed.

4.1 Research Design

4.1.1 Qualitative Research Design

To our knowledge there are no empirical studies that examine the transfer and transformation of tacit knowledge in NPD. Outside the realm of NPD, some research has explained the importance of tacit knowledge; some others have discussed how tacit knowledge may be enabled. However, the majority of the discussions are somewhat incomplete. It was necessary to use qualitative research techniques to accommodate a more in-depth exploration into a number of areas to provide a broader and clearer picture of tacit knowledge transfer and transformation in the context of NPD⁵. Marshall and Rossman (1989) argue that qualitative research techniques provide a depth and richness of research findings that other research methods often don't achieve.

This research uses three qualitative methods to conduct the data analysis and build research conclusions: case study, in-depth semi structured interviews and qualitative data analysis.

4

Van Maanen et al. (1982) state that exploratory techniques are necessary when the meaning, definition and the model are yet to be researched.

5

Marshall and Rossman (1989) state that relationships that have not been previously identified and encompassed in theory require the use of qualitative techniques.

Recall from Chapter Three that six areas pertaining to this research subject have been explored, of which three have been framed as propositions. These six areas of qualitative exploration form the base of each case study and the base of the semi-structured interviews. See below for a broader description of these targeted areas of exploration, formerly outlined in Chapter Three.

4.1.2 Targeted Areas of Qualitative Exploration

- An exploration of the temporal nature of tacit knowledge. The temporal nature explored the relative emphasis on tacit and explicit knowledge and the relative emphasis on different tacit knowledge types at different phases in NPD.
- An exploration of how the transfer and transformation of tacit knowledge occur within and between teams during NPD. This objective examined the senders and the recipients of tacit knowledge transfer and transformation and the processes of tacit knowledge externalization and amplification as mechanisms of tacit knowledge transfer and transformation.
- An exploration of the problems/obstacles associated with achieving the tacit knowledge transfer and transformation and an examination of the obstacles associated with leveraging tacit knowledge at each phase of development. Here we examined knowledge breakdowns⁶ within the core team and between NPD teams, and examined the reasons for these breakdowns and whether they are due to an insufficient tacit knowledge transfer or codification. We also explored other aspects of NPD failure and whether it was due to the insufficient transfer of tacit knowledge.
- An exploration of the factors that encourage the transfer and transformation of tacit knowledge at each phase of development.
- An examination of team composition and its effect on the tacit knowledge transfer and transformation processes. In particular we examine: a) the degree of heterogeneity/homogeneity (knowledge sets) within the core NPD team and analyze its effect on the team's ability to transfer and transform tacit knowledge, and b) the degree of shared mental models within the core NPD team and analyze its effect on the team's ability to transfer and transform tacit knowledge.
- An examination of the level of trust within and between NPD teams and an analysis of this

6

Knowledge Breakdown - Knowledge breakdown was described as a situation where the context or contents of knowledge transfer, message, or information was misinterpreted.

effect on the tacit knowledge transfer and transformation processes.

4.2 The Sample

4.2.1 The Population

The population for this study was defined as technology firms that are engaged in the development and commercialization of new technology products. New product development is classified into two areas, radical and evolutionary. Radical NPD can be described as breakthrough innovations and evolutionary NPD can be described as evolving through a previously developed product (Veryzer, Jr., 1998). It should be noted that, although the development of these two projects types typically fall under the guise of NPD, the processes employed can differ. Radical NPD tends to be more exploratory and less customer driven in the initial phases and also tends to develop prototypes at an earlier phase during the development cycle (Veryzer, Jr., 1998). In two of our three cases we analyzed the tacit knowledge transfer and transformation processes of an evolutionary new product. In the last case study there was some examination of tacit knowledge within a radical NPD process.

4.2.2 Sample Frame

The companies that participated in this research were selected primarily for their fit with the population definition, their size and their willingness to comply with the study in general. The companies that were chosen differ in size as measured by the number of employees engaged in NPD. One company is a multinational telecommunications firm. The choice of this firm is particularly important because of the large number of employees engaged in NPD and because of the more formal NPD roles and processes that this firm has compared to the other smaller companies participating in this research. This difference is particularly important to this study

because it provides the opportunity of assessing whether formalized NPD links and processes will improve the tacit knowledge transfer and transformation effectiveness.

4.2.3 Unit of Analysis

In the interaction of the team and its need to complete phase dependant and team dependant tasks, we analyze the transfer and transformation of tacit knowledge, and the obstacles/barriers of the process and promoting factors of the process. We could also say that the entire firm could also be the unit of analysis where this process is analyzed, but we have narrowed the unit of analysis to the transfer and transformation process within and between NPD team(s) at each phase of development.

4.2.4 Case Study Approach

A case study approach was used in this research. Case research provides a grounded approach to our research given the newness of this subject matter (Cooper and Schnidler, 1998)⁷. In each of the three cases we investigated and compared the processes of tacit knowledge transfer and transformation at each phase of development, from idea generation to product launch.

The case research methodology of Yin (1994) has been followed. According to Yin there are several important components of sound case research design.⁸ Our research design attempts to

7

Cooper and Schnidler (1998) state that case research will provide the opportunity for developing a full contextual analysis, as such it can provide a source of new hypothesis and constructs for the advancement of new theory.

8

According to Yin (1994) there are several important components to sound case research design: well defined and supported study questions, a well defined unit of analysis, sound logic linking the data to the propositions, and sound methods for analyzing the research findings.

fulfill these areas.

1) *Well defined and supported study questions*: Many of the targeted areas of research pursued in this thesis were derived in part from a number of credible research sources who have explored tacit knowledge as it exists in organizations and teams. Their work has aided the development of our conceptual models and interview questions (see Chapter Three for the development of the conceptual models and discussions). 2) *A well-defined unit of analysis*: the unit of analysis within our research was clearly defined as the interaction of the team at each phase of NPD. In the interaction of the team and it's need to complete phase dependant tasks we analyzed the transfer and transformation of tacit knowledge and other related factors of the process. 3) *Sound logic linking the data to the propositions*: the case research makes use of in-depth semi structured interviews to collect data. The interview questions have been derived directly from the targeted areas of research and hypothesis outlined in Chapter Three. This has been done to establish a link between the targeted areas of research, the propositions, and the data collected. 4) *Sound logic for analyzing the research findings*: multiple cases were chosen for comparison purposes. Theoretical replication refers to the use and comparison of case studies that are similar in some ways but dissimilar in others so as to "produce contrary results but for predictable reasons." The evaluative methods used for interpreting the data consists of within case evaluation and cross case evaluation considered to be sound for case research (Yin, 1994).

A case protocol, which included the development of an interview instrument and interviewing protocols was developed and used based on recommendations on interviewing by Yin(1988) and Seidman (1998). To begin with, an interview pretest was conducted in another firm. According to Yin (1989), this can help ensure that the final instrument and interview protocol are valid. Once

the protocol and interview instrument was sufficiently developed it was used to interview individuals from a variety of different functions involved in the development of the same new product (Phillips, 1981).

4.2.5 Evaluative Criteria of Qualitative Research and Case Study Approach

Well-designed case studies can be informative and rigorous (Yin 1989). There are at least four criteria that contribute to the rigor and the quality of the research: construct validity, internal validity, external validity and reliability.

Construct validity refers to whether the constructs or categories that emerge from the research are valid. To ensure construct validity we have attempted to establish correct operational measures for the concepts being studied. We feel that this research has achieved this. We introduce two operational measures that describe how the transfer and transformation process can occur effectively, namely the processes of tacit knowledge externalization (Nonaka and Konno, 1998) and amplification (Numata and Taura, 1996, Leonard and Sensiper, 1998), see the conceptual model, *The Transfer and Transformation of Tacit Knowledge in NPD*, Figure 7.

Internal validity deals with the relationship between dependant and independent variables. To ensure internal validity we have argued and proposed causal relationships. In this research, internal validity was increased through the use of pattern matching and explanation building (Yin, 1989), (refer to Chapter Five and Six, data analysis and findings). However, ultimately case research is exploratory in nature and no statistically valid declaration of absolute relationships can be concluded.

External validity is concerned with the generalizability of the research results. As we pointed out before, case research does not produce statistically valid research results that can be generalized to other areas, however within the context of the case study approach we attempted to maximize external validity through the use of multiple case studies (Yin, 1989).

Reliability refers to the repeatability of the study. To ensure reliability, a good case study attempts to demonstrate that the case study questions and protocol (involving data collection procedures) can be repeated to achieve the same results. In this research the reliability of the case study method was increased through the use of interview protocol (interview questions and presentation materials) which provided a better understanding of the interview questions to the interviewees. The interviews were also recorded, transcribed and stored for later use. Any researcher who wishes to use the same data set will most likely arrive at the same results.

4.3 Method of Data Collection

4.3.1 Sampling Unit for the Interviews

Following the systematic replication logic advocated by Yin (1994), interviews were conducted with individuals from different functional areas of NPD, and involved at different phases of NPD. This was done to ensure that the process of tacit knowledge transfer and transformation was fully examined from different functional perspectives. Table 1 below provides a list of individuals interviewed at each company and their corresponding functional involvement in the NPD process of each new product examined.

Table 1 - Interviewee Disciplines

Interviewees	Company A	Company B	Company C
Interview no. 1	Information Resource Center, Competitive Intelligence (not directly involved in NPD process)	Engineering-Project Leader	Engineering-Networks
Interview no. 2	Junior Software Engineer	Engineering/MBA: Product Line Management Prime	Engineering-Chief Software Architect
Interview no. 3	Engineering-Engineer Manager	Engineering-Senior Portfolio Mgmt. Team and Project Leader	Business-Product Line Management
Interview no. 4	Engineering/MBA: R&D Organizational Learning	Marketing-Marketing Prime	Business- Product Line Management
Interview no. 5	Engineering/MBA: Managing knowledge transfer from universities and government research centers	Engineering-Hardware and Software Development Prime	Senior Consulting Software Engineer
Interview no 6	Engineering-Network Solutions	Engineering-Hardware Development	Software Architect
Interview no. 7	Team Facilitator	Engineering-Customer Support	Engineering-R&D
Interview no. 8	Engineering-Process Development	Engineer Manager - Testing and Verification	Business-Product Line Management
Interview no. 9	Senior Engineer	Engineering/MBA: Manufacturing Prime	Consulting Software Engineer
Interview no. 10	Team Facilitator (not directly involved in NPD process)	Manufacturing Quality and Assurance	Quality and Assurance Manager

4.3.2 Pre-test

According to Cooper and Schindler (1998) pretesting the instrument is recommended to identify problems before the actual collection of data begins. Three pre-tests of the interview questions were conducted. The pre-tests were conducted in order to check the flow of questions, suitability, clarity, and language used. Based on feedback from these individuals we found that some of the words used to describe tacit knowledge and tacit knowledge transfer and transformation was not well understood. From this it was decided that some of the words used in the interview would be changed, and that interview protocol would be developed and used for the purpose of describing some of the more complex concepts used in this research. The language used in the interview questions were modified slightly, for example, words like tacit knowledge transfer and transformation were changed to knowledge transfer and knowledge building. The interview protocol is described next.

4.3.3 Interview Protocol

Before each interview was conducted a two page introductory sheet was e-mailed to each interviewee. A copy of this document can be found in appendix A. The two page document provided a brief description of the research, contact names associated with the research, and described how interviewee confidentiality and anonymity would be maintained. A five minute presentation was also conducted before each interview. A series of diagrams was used to describe the distinction between tacit and explicit knowledge (figure 1 - Chapter 2), the areas of exploration (Targeted Areas of Qualitative Exploration - Chapter Four) and the conceptual models (Figure 5,6,7 - Chapter Three).

All interviews were conducted face to face at the location in which the NPD team of each company was physically situated. The interviews lasted approximately one and a half to two hours. Interviewees were asked permission to tape the interview. One interviewee declined, the rest were taped and later transcribed. Every effort was made to eliminate interview bias. For example, interviewees were not prompted for specific answers. Many questions were open ended.

4.3.4 In-depth Semi Structured Interviews

In-depth semi structured interviews were used to collect the data.⁹ The main objective was to collect data on the six targeted areas of exploration pertaining to tacit knowledge transfer and transformation at each phase of development. All Interviewees were asked for examples when responses to questions were provided. By asking for examples, the nature of a process can be uncovered and a better understanding of the associated variables achieved. Follow up questions were used in the interview methodology to help confirm or refute underlying assumptions and/or important issues which required clarification (Patton 1990).

4.4 Data analysis

Qualitative analysis techniques were used to analyze the data. The data was collected and transcribed literally from taped conversations. Each interview was coded and analyzed on a question by question basis. The qualitative analysis process can be described as having six phases: 1- first organizing data according to the six targeted areas explored, 2- generating

9

Because this research is exploring an area where theory is yet to be built, the data collection method can not be a survey or an experiment. The data collection method has to provide for some basic structure but mostly has to be built in openness to the unexpected, to new findings, and it has to retain a flexible design that fosters the exploration of nuances in complex processes.

categories within each area, 3- searching for themes and patterns within each case, 4- summarizing common themes and interesting findings from cross case analysis, 5- validating and expanding the conceptual framework against the summary of common themes, and 6- deriving the final conclusions and implications of the research based on the findings and the expanded framework.

4.4.1 Analysis of Interview Data

The exploratory nature of this study dictated that much of the analysis be descriptive. The six areas pertaining to tacit knowledge transfer and transformation were examined within each phase of NPD. Questions were coded and analyzed on a question by question basis. Although the same issues were examined at each phase, the questions for each phase were coded differently in order to facilitate cross phase (for the same new product) and cross case comparisons. When appropriate, content analysis was used to analyze the responses. According to Cooper and Schindler (1998, p. 417), "content analysis is useful for measuring the semantic content or the what aspect of a message." A standardized analysis mechanism, a code book was established to compare company responses within and among the three cases.

4.5 Interview

4.5.1 Interview Framework

The interview questions satisfy Yin's case research methodology (1994).¹⁰ The interview consisted of in depth semi-structure interview questions and took approximately 1.5 to 2 hours of

10

In depth semi structured interviews will be more appropriate for the discovery of new and relevant variables, relationships and deep patterns that can only be observed in detailed descriptions provided by interviews subjects. Yin (1994) says that effective interview questions in case research will answer the research questions, satisfy the research model and involve the correct unit of analysis.

the interviewee's time to complete. The questions covered three areas: (1) personal information (2) background information (3) questions which address the six areas of investigation pertaining to tacit knowledge transfer and transformation.

This research is exploratory and as such the goals of data collection and analysis must be built in openness to the unexpected and to new findings. Because of this, most of the questions in the interview were open-ended questions. Open-ended questions provided an interviewee with the freedom to answer the questions using their own descriptions. This condition is important as it allows for unobstructed exploration. Most questions also make use of the word why. Patton (1990) believes that frequent use of the word why in interview question structuring helps to identify and establish cause and effect relationships and patterns.

4.5.2 Outline of the Interview Questions

This interview has six main sections:

Section 1: Basic Personal Questions - For follow up purposes.

Section 2: Background Questions - The background questions will be used to interpret the findings and also provide an understanding of an interviewee's tacit knowledge base.

Section 3: Preliminary Questions - Preliminary questions will be used to provide an understanding of how the new product development (NPD) process works in each company.

Section 4: Target Questions - Target the areas of qualitative research pertaining to tacit knowledge transfer and transformation. These are listed below:

- ▶ What is the relative emphasis on explicit and tacit knowledge, and the relative emphasis on different tacit knowledge types at different phases of NPD?
- ▶ How is tacit knowledge transferred and transformed at each phase?
- ▶ Who are the senders and the recipients of tacit knowledge transfer and transformation at each phase of NPD?
- ▶ What are some of the problems/obstacles associated with the tacit knowledge transfer and transformation and associated with leveraging tacit knowledge at each phase of NPD?
- ▶ What are some of the factors which enable the transfer and transformation of tacit knowledge at each phase?

- ▶ How does the degree of heterogeneity/homogeneity (knowledge sets) and the degree of shared mental models within each core team affect its ability to transfer and transform tacit knowledge?
- ▶ How does the degree of team trust present within a core NPD team and between NPD teams affect their ability to transfer and transform tacit knowledge?

Section 5 - Some interviews were scheduled with individuals who play an indirect role in the NPD process. Questions were changed slightly to fit this type of a role. Refer to Table No. 1 page 54 for individuals who were not directly involved in the NPD process.

Section 6: Tacit Knowledge Audit - The tacit knowledge audit exists to collect data outside those areas above which may support the transfer and transformation of tacit knowledge in NPD. Many of these factors have been addressed in the literature review. They have been put into the format of a likert scale to provide a quick assessment of a number of other factors which support knowledge sharing and tacit knowledge transfer and transformation effectiveness in each company. This information was used to provide more understanding during the data analysis process.

4.5.3 Interview Questions - See Appendix A for the interview questions.

Chapter Five: Data Analysis

This chapter is divided into two sections. Section 1 provides descriptive data for the three companies that participated in this research. In particular their NPD methodology and processes are outlined and compared. This information will be referred to in the data analysis. It will also provide contextual information helpful for within case and cross case comparisons.

Section 2 provides the results of the data analysis. Recall that six areas of data related to tacit knowledge transfer and transformation (See Chapter Four-Targeted Areas of Qualitative Exploration) were collected and analyzed within each company. This chapter provides a summary of common and interesting findings from the data analysis. This chapter also reports the results of the propositions formerly outlined in Chapter Three.

The specific order in which this analysis has been laid out will help to provide a cumulative understanding of the subject matter. First we present the most common findings of when tacit knowledge is used in the NPD process, followed by how tacit knowledge is transferred and transformed at various phases, then problems and barriers to effective knowledge transfer are presented, followed by factors that enable the tacit knowledge transfer and transformation process. An analysis specific to each of the companies can be found in Appendix B. Tables and additional information that were deemed too long to be included yet provide support for comments made are also found in appendix B.

5.1 Descriptive Data

The companies that have participated in this research are Canadian-based technology firms that are engaged in the development of new technology products. Three companies have participated in this research, we refer to each company by an abbreviated name that describes the products that each company develops. One company is a small firm that develops business **software products**, we refer to this company as **Soft-Co**. Another company is a small to mid size firm that develops business **communication products**, we refer to this company as **Comm-Co**. The third company is a large multinational company which develops networking and **telecommunication products**, we refer to this company as **Tel-Co**.

5.1.1 Descriptive Data - A Comparative Summary of Soft-Co, Comm-Co and Tel-Co

Table 2 - Miscellaneous Data, Soft-Co, Comm-Co and Tel-Co

Variables	Soft-Co	Comm-Co	Tel-Co
Industry	Business Software	Networking & Comm.	Networking & Telecom.
Dispersed or Central Location of NPD Activities	Centralized	Centralized	Dispersed
Type of Project Structure Used	Matrix	Matrix/functional	Matrix/project
Innovation Rate (2000): % of new products vs. % continuous products developed	20% new product development, 80% continuous product development	10% new product development, 90% continuous product development	60% new product development, 40% continuous product development

Table 2 shows that the ratio of new to continuous product development differs markedly among the three companies for the year 2000. The principal focus of Tel-Co is on the development of new products. Perhaps because of their continued focus on new over continuous development, their NPD process is highly structured and sophisticated next to that of Soft-Co and Comm-Co.

Tel-Co uses a system of business processes, formal NPD roles and structures to facilitate NPD, they also make improvements to their NPD system based on the continuous evaluation of lessons learned. Their system has established links between their core team and other NPD teams, which has appeared to facilitate knowledge transfer at Tel-Co.

You will notice, that Soft-Co placed more emphasis on NPD activities than Comm-Co in the year 2000, although overall Comm-Co has developed more new products than Soft-Co.

Comm-Co has also defined and created standards for their NPD process. Soft-Co presently has no formal NPD system and is much smaller in size (as measured by the number of R&D activities and employees) than Comm-Co and Tel-Co. Their product base had been built through a combination of NPD and by acquiring products from other companies. They noted that if they were to develop more new products in the future then more effort would be placed on developing NPD standards, processes and building on lessons learned. At the time of this study, co-location and face to face interaction of NPD employees appeared to be the main catalyst for tacit knowledge transfer at Soft-Co.

Figure 8 below outlines the NPD processes practiced at each company. As mentioned above, Comm-Co and Tel-Co have documented their NPD processes, Soft-Co has not. However, in our discussions with engineers at Soft-Co we were able to extrapolate the most common NPD process used by many of the NPD project leaders.

Figure 8: NPD Process of Soft-Co, Comm-Co and Tel-Co

5.1.2 Small Software Company: Soft-Co

NPD Methodology of Soft-Co

Soft-Co has no formal process for developing new products. The NPD processes used are guided by the senior management team responsible for the development of the new product. However, the development philosophy of Soft-Co was described as generally being of the Iterative Software Development School or the Prototyping School of Development. Typically users often know many of the objectives they wish to address with a system but they do not know all of the nuances of the data and the implications of the objectives. The Prototyping Model was described

as offering a development approach that yields results without requiring up-front information. Many iterative sessions of tacit knowledge transfer and transformation are generally required before the prototype is developed with this type of development process.

For example, with one NPD project at Soft-Co, they started by developing an abbreviated version, a prototype of the system which performed a limited subset of functions. Other features were then added on in incremental development steps, where sales and tech support provided some feedback on the basic design and functionality of the product. One process of feedback was described as being similar to a mini Waterfall Process¹¹, where feedback from one phase provides vital information into the design of the next phase. At Soft-Co the product is initially divided up into smaller pieces for prototype development on each piece and then integrated later on.

Unlike many technology firms, Soft-Co does not focus prominently on a time to market development environment, as Tel-Co and Comm-Co do (not being constrained by time can be beneficial to the transfer and transformation of tacit knowledge). Soft-Co argued that developing new software products that are constrained by a timely development process can be counter productive toward innovative and quality software development. Hence, in recent years Soft-Co has shifted from less focus on timely development to more focus on quality development. However it should be noted that the process of development for continuous products at Soft-Co has more standards and process, and is focused on timely development. Soft-Co has NPD core team members that come into the development process at different phases. A list and description of a typical NPD core team at Soft-Co is provided below.

11

Waterfall Model (Kal Toth, Intellitech Consulting Inc. and Simon Fraser University, 1997): The Waterfall method consists of the following sequential steps: system conceptualization, system analysis, system design, coding and testing.

Soft-Co NPD Core Team Description:

- **Project Leader:** The main objective of the Project Leader is to make sure that a compelling product is produced. He/she is also responsible for the high level management of the core team. Not only does this individual transfer (tacit knowledge) technical know-how to other members of the core team but also provides the guidance needed to understand and integrate the technical and market requirements (often critical to NPD success). This know-how comes from a deep understanding of the existing customer base and years of NPD experience.
- **Product Champion:** This individual is responsible for championing the NPD initiative.
- **Project Manager:** This individual is responsible for the implementation of the project plan. This role becomes more important once the initial prototype has been designed and the development of the product is underway.
- **Product Management:** At a high level, this individual is responsible for bringing customer requirements into the development process. Initially, the Product Manager spends time out in the field trying to attract the customer to the development process so that this feedback process can be initiated. Once contact has been established, customers are walked through the business model and problems. Product Management is then responsible for communicating and translating the customers' feedback (Tacit knowledge transfer) from these sessions to Design, Development and Quality and Assurance. They are also responsible for educating the sales force on the new product features.
- **Senior Developer, also called Consulting Software Engineer:** This individual is responsible for writing and designing software for prototype and beta¹² development. He or she is also responsible for communicating (tacit knowledge transfer) the high-level design expectations to the core team.
- **Senior Architect:** This individual is responsible for high-level product design and implementation.
- **Testing and Verification - Quality and Assurance Manager:** This individual is responsible for managing the testing and verification of the new product.
- **Marketing Support:** This individual is responsible for developing the product marketing plan. He or she is also responsible for providing customer feedback to Product Management.

Most knowledge transfer occurs informally at Soft-Co. Many of the employees who work on new product initiatives are co-located. There are formal meetings, however much of the software innovation and knowledge building requirements of each phase occur through informal, face to face meetings.

12

Beta refers to the first phase of software development after the first level design (prototype) has been completed. A simplified version of the proposed system (prototype) is developed and presented it to the customer for feedback. The first cycle of feedback from the customer is called Beta, subsequent cycles of customer feedback are called Beta 1, Beta 2 and so on. Often the prototype code is thrown away during Beta and entirely new programs are developed when customer requirements are firmly identified.

A Closer Look at the NPD Process of Soft-Co

Phase 1: Idea Generation - New product ideas at Soft-Co come mainly from highly experienced, senior engineers within the new products division of the company. These individuals' possess engineering software expertise and a good understanding of customer problems and needs. Some new product ideas are also derived through feedback from Product Management who liaise closely with the customer to understand customer problems and requirements, and from the Business Development Team who run the strategic plan of the company and set the tone and direction of new products at Soft-Co. As per Leonard and Sensiper (1998), these types of tacit knowledge transfer can be more appropriately labeled as guiding tacit knowledge.

Soft-Co has a strong champion oriented culture. New product ideas take on life through a development champion who believes in and oversees the initial development of the prototypes. This person also tends to be the originator of the idea. The ongoing success of NPD depends on high levels of technical tacit knowledge transfer from this individual.

Phase 2: Investigation - The objective of this phase is to define the product further in terms of production, competitiveness, and acceptance by the existing customer base. An investigation team is formed to fulfill the objectives of this phase. It consists of four to five individuals, usually a mixture of senior developers, architects and marketing people. The Marketing persons of this team typically provide input by identifying the market in greater detail and assessing product differences with competing products. Engineering and Product Line Management define the high-level product requirements. Successfully fulfilling the objectives of this phase is dependant largely on the transfer of diverse and high levels of experience (tacit knowledge) of the team members. This phase is generally two to three months in length.

Phase 3: Prototyping Phase - The senior developer and architect of the previous phase usually remain in this phase to begin researching the prototype development. Their work is highly iterative and interactive with one another. Ideas are exchanged back and forth in many informal face to face meetings. The first prototype of the product is ready when all critical pieces of the product idea have been individually designed and coded. The total number of people in this phase is dependant on the number of product pieces, typically this number is anywhere between twenty and thirty people (two to three people are often responsible for the prototype development of each product piece). This phase is approximately one year in length.

The Product Manager also plays an important role in this phase. Product Management works closely with each smaller development team to ensure that customer requirements are compiled and integrated. They produce what is called a Requirements Document which consists of a list of customer requirements. Approximately forty percent of the contents of this document come from Marketing, twenty five percent from Development, and thirty five percent from Product Management.

Phase 4: Integration - Integration of the product pieces occurs during this phase. To ensure quality integration and a final product that is robust, many face to face iterative discussions (tacit knowledge transfer and transformation) occur between each smaller Development team and the Quality & Assurance (Q & A) team. The Field Support Software Specialists also work with Design and Q & A by conducting test applications of the product with customers. This phase is approximately one to one and a half year in length. Phase four and five are largely dependant upon tacit knowledge transfer within teams and between teams.

Phase 5: Commercialization Phase - This phase involves the implementation of the marketing plan. Product Management plays a role in this phase, they are available to customer support and the sales force for product information. This phase is approximately four months in length.

Mechanisms of Vertical and Horizontal Tacit Knowledge Transfer at Soft-Co:

Several mechanisms for tacit knowledge transfer have been observed at Soft-Co. They have been classified under vertical and horizontal tacit knowledge transfer.

Horizontal tacit knowledge transfer is referred to as the transfer of tacit **Inter**-product knowledge required for continuous improvement of products and processes. This can also be described as NPD lessons learned and transferred between different product groups within the company. The knowledge is more typically transferred in the form of stories and examples.

Vertical tacit knowledge transfer is referred to as the transfer of tacit **Intra**-product knowledge required for the development of the product.

Mechanisms of Vertical Tacit Knowledge Transfer.

- ▶ **Weekly NPD Meetings:** These meetings act as a vehicle for problem solving and for discussing project deliverables. Vertical tacit knowledge transfer occurs when product development problems are jointly solved. Guiding tacit knowledge between team members is also transferred during the group's discussion and joint decision making on project deliverables.
- ▶ **Co-location:** Knowledge exchange that is needed outside the weekly meetings is enabled by co-locating NPD employees. Co-location of the NPD team facilitates the process of

vertical tacit knowledge transfer. If product knowledge and information are required then team members can easily acquire it through informal meetings and chats.

- ▶ Bi monthly meetings for product integration: During these meetings the Integration groups present what they have, and NPD core team present what they need. Both teams then arrive at an agreement on what the team will do to enable the development of a quality product. Vertical tacit knowledge transfer occurs during discussions. During these discussions, diagrams, examples and stories are often exchanged. This type of communication often enables the effective transfer of tacit knowledge.
- ▶ Informal buddy system: An informal buddy system is often used within Soft-Co. Younger engineers are often coupled with senior engineers to ensure that product knowledge transfer and learning (vertical tacit knowledge transfer) occurs.
- ▶ The use of integrated parallel NPD processes at Soft-Co during NPD offers greater possibilities of vertical tacit knowledge transfer. Software field support, sales training and documentation are often done in parallel during the design and development phase. A continuous feedback loop is often established between these parallel processes. Field support staff are brought into the design center to work with the design staff by offering real customer applications that help to shape the quality and direction of the product. Similarly, the documentation group and sales staff are also involved in the design process by providing feedback on the design and to learn about the product (vertical tacit knowledge transfer). By paralleling these processes and developing links that ensure tacit knowledge transfer between these processes, it was reported that the quality of the product and training and documentation improved. Also reported was that the field support and the sales force were more ready to provide quality support to customers immediately after product launch.

Mechanisms of Horizontal Tacit Knowledge Transfer:

- ▶ Quarterly meetings: During this meeting new products are demonstrated. Demonstrations often include diagrams explaining the technical aspects of the product, followed by live examples of how the product works and what the benefits are. Live demonstration can be an effective method of transferring technical tacit knowledge.
- ▶ Development Day: Customers are invited to explain to engineers what they want to accomplish at their companies with Soft-Co's products. Soft-Co has found this type of horizontal tacit knowledge transfer to be extremely effective because it acts as a form of guiding tacit knowledge.
- ▶ Development Code Reviews: Software developers present to other developers their methods of software development on current development initiatives. These meetings are intended to act as feedback sessions, where one developer presents, two developers critique and one developer observes. They have found that this method is extremely powerful for transferring lessons learned (horizontal tacit knowledge transfer). These meetings are usually scheduled twice a week.
- ▶ Quality Assurance Code Reviews: Similar to development code reviews above. Quality Assurance Analysts present to other analysts in their field their methods of testing on current development initiatives. These meetings are usually scheduled once every two weeks.

5.1.3 Medium Size Business Communications Company: Comm-Co

NPD Methodology of Comm-Co

Comm-Co uses a NPD methodology that has been developed through the consulting firm

PRTM. The PRTM product development methodology is referred to as Pace¹³. The focus of Pace is principally on the management of the product through its business cycle. Pace suggests several management techniques that are intended to reduce the time to market of the product, such as a core team approach, a structured development process, and various development tools and techniques. It also suggests reevaluating the strategic fit of the product and its business opportunity at each phase. Comm-Co is of the belief that companies developing new products should focus on what the business implications are, not the specific technology solutions.

Two principal areas have been targeted within the NPD methodology of Comm-Co. Firstly, Comm-Co believes that for quality product development to be achieved, the continuity of knowledge must be maintained between phases. They believe that this continuity of knowledge can be achieved through the use of a core team approach and by ensuring that the members of the core team do not change during the NPD process. In a new product development world, often different groups are producing different pieces. Comm-Co also argues that the core team approach facilitates this process of bringing those different pieces together and facilitates the transfer of tacit knowledge across functions. A description of a typical NPD core team at Comm-Co is provided.

Comm-Co NPD Core Team Description

- Core Team Leader: This individual is responsible for leading and managing the overall development of the new product. Guiding tacit knowledge is typically transferred from this individual to communicate project expectations (usually in the form of examples outlining previous project successes).
- Project Manager: This individual is responsible for project schedules, overall task allocation,

13

Product and Cycle-time Excellence. The Pace model has been referred to as a business cycle focused methodology.

the distribution of standard project information, the minutes from core team meetings and for ensuring that all problems are accounted for and solved on a timely basis. This is accomplished mostly through the transfer of explicit knowledge.

- **PLM (Product Line Management):** This individual is responsible for gathering information on the requirements of the product, the strategic fit and financial information. Product line management communicates directly with finance to develop the financial analysis and also works with portfolio management to establish the strategic fit of the project.
- **Marketing:** This individual is responsible for gathering the following marketing information: market trends, competitive information, segment research, market channel information and the customer requirements.
- **Engineering:** This individual is responsible for managing and ensuring the overall design, development, and testing and verification activities of product development. He or she relies on functional team members from Design and Development and Quality Assurance to accomplish these tasks. Much of this ongoing development is accomplished through iterative meetings between design and testing and verification. Guiding these processes forms the basis of this individual's work.
- **Product Supply:** This individual is responsible for ensuring that the prototype production is completed, and that materials forecasted and manufacturing processes are established for volume production.
- **Regional Team Leader:** This person is responsible for establishing regional sales and customer support where necessary.
- **Sales:** This person is responsible for establishing sales forecasts and sales training programs.

Secondly, in terms of the process of developing new product ideas, Comm-Co is also of the belief that sources for new product ideas should be encouraged from all departments. Before an idea gets developed and commercialized, they argue that it must be analyzed by a senior team who ensures that the idea is in line with the overall direction of the company and that it has business potential. Comm-Co refers to this team as the Project Approval Committee (PAC)¹⁴.

Most of the tacit knowledge transfer that happens within this structure occurs informally through the co-location of the core team members and the co-location of functional members. There are some suggested avenues for formal knowledge transfer during NPD, such as weekly core team

14

Project Approval Committee (PAC) - This term is used to describe a senior management group that has the authority to accept or decline new product ideas and also has the authority to halt product development at any phase during the NPD process. At Comm-Co this team consists of senior people in the areas of R&D, sales, marketing, finance, and spending.

meetings and business decision meetings at each phase.

A Closer Look at the NPD Process of Comm-Co

Phase 1: Pre-Concept - Comm-Co has developed many sources which help to encourage and promote the incubation of new product ideas, these are listed below. Ideas are loosely evaluated based on their potential business opportunity and strategic fit with the company. If the Project Approval Committee agrees that the product idea looks like a good business opportunity and it fits with the overall strategic direction of the company then a Concept Team is formed to evaluate the new product idea more closely. Comm-Co believes that many of their new ideas have been developed in environments where tacit knowledge was able to flow and be transferred freely. They believe that their creation of a team, *Strategic Technology Team*, whose main mandate is to introduce new ideas into the firm, placed importance on the exchange of ideas and promoted the transfer and transformation of technical tacit knowledge.

Idea generation sources:

- **Strategic Technology Group:** This group liaises with the academic community and government research organizations (ie. NRC, CITO, OCRI) with the intention of bringing back ideas, new product ideas and new R & D tools. The strategic technology group will then transfer this knowledge (tacitly and explicitly) through demonstrations of the prototypes or R & D tools to R & D groups in the company. Between five and ten percent of the ideas brought forth by the strategic technology group are used. This group is also responsible for attending external conferences with the purpose of bringing back new ideas. They also develop internal conferences with the purpose of sharing and generating new ideas within the company. Much of their tacit knowledge transfer is accomplished through demonstrations.
- **University Collaboration or NRC Collaboration:** The Strategic Technology Group of Comm-Co enters into a contract with a university, college or government organization to fund and/or develop collaboratively a new technology with the hope that this technology can be commercialized.
- **The pursuit of new product ideas from all employees is encouraged by top management at Comm-Co.** An open door policy exists with employees from all disciplines to discuss new product ideas with senior executives.

- Comm-Co has incentive systems which encouraged the generation of new product ideas. There are patent awards which give cash prizes for developing patentable new products and also innovation awards which provide cash prizes for new product and business ideas. Cash prizes can be as high as ten thousand dollars.

Phase 2 - Concept Phase: The Concept Team usually consists of a couple of engineers and a marketing person. The engineers of this group are usually the creators of the new product idea. Here, the Concept Team will investigate the product concept, assess the strategic fit, loosely evaluate the market opportunity and assess the preliminary cost and time of full scale product development activities.

The Concept Team is usually influenced most by how the idea can be differentiated from other products at this phase. Comm-Co also refers to some members of the Concept Team as Abstractionists, a term used to refer to a distinct skill set and experience that becomes critical to effective high level project assessment necessary at this phase. These individuals can share and develop ideas quickly and can communicate quite effectively the constructs of the product in a clear manner to others. Some Abstractionists also understand some depth of the technology (code) so they are able to comprehend where the technical limits of the product are. Their effective transfer of tacit knowledge on these new product issues is critical to the ongoing success of the project. Because few individuals at this company are reported to have this skill set, Abstractionists tend not to transition to the core team but instead continue assessing other new products ideas that enter into the concept phase of development. In general, this phase takes anywhere between six to eight weeks. The product development process progresses after the Concept Analysis has been reviewed by the PAC committee and there is an agreement that product development should continue.

Phase 3 - Analysis Phase: The Concept Team evolves into a core team. One member of the Concept Team is encouraged to work with the core team to ensure that the continuity of knowledge (tacit knowledge transfer) occurs from the Concept Team to other core team members. Ideally the core team is developed with seven or eight members, many from different disciplines (refer to page 79). The core team is present in the analysis phase to validate the assumptions in the Evaluation Report brought forth by the Concept Team. Focus is placed mainly on a thorough business analysis. Also, detailed at this phase are the product definition, the technical approach and the project plan. A good deal of reflection and tacit knowledge transfer occurs between core team members before a consensus is arrived at. In general this phase takes anywhere between eight and twelve weeks. The Project Approval Committee must again evaluate whether the product development process should continue or be halted.

Phase 4 - Implementation Phase: This phase involves the implementation of the project plan through the core team who manage and work in conjunction with functional staff to develop, test, establish manufacturing processes and begin commercialization of the product. Many iterative meetings are involved in this process before the product is finished.

Phase 5 - Rollout Phase: The main activities in this phase are the mass manufacturing of the product and establishing sales and customer support plans. The end of phase five signifies the completion of new product development activities at Comm-Co.

Mechanisms of Vertical and Horizontal Tacit Knowledge Transfer at Comm-Co:

Several mechanisms for tacit knowledge transfer can be detected at Comm-Co, they have been classified under vertical and horizontal tacit knowledge transfer (see page 75 for definitions of

vertical and horizontal tacit knowledge transfer).

Mechanisms of Vertical Tacit Knowledge Transfer:

- Core team meetings: These meetings act as a vehicle for problem solving and discussing project deliverables. Vertical tacit knowledge transfer occurs when product development problems are solved jointly.
- Buddy system: no official buddy system exists, but this technique of (vertical) tacit knowledge transfer is used by many of the engineering managers within Comm-Co. New employees will at times enter into an NPD process during the process. A new employee will at times often be coupled with a longer term NPD employee, typically someone who has been working on the project from the beginning. Important technical issues related to the project are often best transferred effectively through repeated informal tacit knowledge transfer and through observation, by watching and listening to the individual perform his/her functions.

Mechanisms of Horizontal Tacit Knowledge Transfer:

- Lunch and learn sessions: speakers from outside the company present and hold discussions on new technologies. These discussions act as a catalyst to effectively transfer tacit knowledge on other products and technologies outside the company.
- Windriver: A service that Comm-Co subscribes to which allows new product developers to talk directly to technology researchers. An opportunity to talk directly to the researcher allows for technical tacit knowledge transfer.
- Virtual training facility: Comm-Co uses video conferencing product training sessions. Visual and auditory connections provide the opportunity for tacit knowledge transfer.

- **Product Training Center:** face to face product training sessions are an effective way to transfer the tacit knowledge of the trainer. These trainers are in general experienced with the technology and with product development.
- **Product demonstration days:** A biannual company wide demonstration of new products being developed occurs at Comm-Co. Each group demonstrates their new product to others. Demonstrations can be an effective way to transfer tacit knowledge.
- **“Social Fridays”:** A weekly social evening that provides an opportunity for employees to socialize and demonstrate technological developments in new and existing product development initiatives.
- **Mentoring Program:** A formal mentoring program exists to transfer know-how between experienced and inexperienced engineers.

5.1.4 Multinational Telecommunications Company: Tel-Co

NPD Methodology of Tel-Co

The NPD framework used by Tel-Co is a system of business processes and structures which focus on facilitating quick time to market of the product, and a process of feedback from the customer early on and throughout the development cycle. Their NPD framework is a derivative of the Pace framework (McGrath, 1997), also used by Comm-Co. Recall that Pace (McGrath, 1997) suggests the use of project management tools like phase review processes, the core team approach, structured development processes and techniques to reduce development cycle time. Tel-Co believes that the current business climate, changes in industry competition, the influx of high-tech start ups and changing customer preferences demanded an NPD framework that would place greater focus on decreasing the time to market of the product and increasing the alignment of the product with customer needs. Tel-Co's NPD framework was developed with this focus in

mind.

Their framework was developed with the purpose of fulfilling the following explicitly stated objectives: greater customer involvement during the development process, developing products which have greater alignment with the strategic direction of the firm, faster time to market, facilitating project and portfolio decisions along the developmental cycle, and more accountability from the core team. They state that this structure reflects and embodies the flexibility of NPD processes and cultural norms typically found in a start up firms.

Their framework outlines the use of a structured development process and a core team approach to accomplish NPD activities. The structured development is a set of flexible guidelines that specify different paths for different types of projects, clarifies linkages between functions, and is focused on the alpha, beta philosophy of rapid customer engagement. The development of the product occurs in incremental development steps. At each incremental development step customer feedback is initiated and integrated back into the development of the product. Alpha refers to the process of engaging the customer early on in the development process for the purpose of clarifying the product definition with respect to the customers' solution early on. Beta refers to obtaining customer feedback on the robustness of the product and feeding that knowledge back into the product development process.

At the heart of this development process is the core team that is accountable for and makes the principal decisions for design, development and customer feedback integration. The core team consists of members from Marketing, Development, PLM (Product Line Management), Global Customer Support, Operations and Finance. These roles are described below.

Tel-Co NPD Core Team Description

- **Project Leader:** This individual is primarily accountable for the project/business results. He or she is also responsible for the allocation of funds across functions, guiding and managing the core team, outlining the main development aspects of the product concept and making decisions on the time frame of the project. Much of this knowledge used to accomplish these functions is tacit based. Stories, examples and anecdotes are typically used to transfer tacit-based knowledge and expectations on NPD by this individual.
- **Project Manager:** This individual is responsible for the overall project schedule, budget, metrics, and cross functional coordination. This individual also takes on the role of the Customer Support Prime.
- **Development Prime:** This individual is responsible for managing the software and hardware development process and reporting on this development progress to the core team. The expertise that is most importance to this individual is understanding how to manage a group of people, how to get the most out of people, and how to manage a project from end to end from a development R & D perspective. These people typically have a lot of development experience so that they can assess what is realistic and what is not from a technical perspective early on in the Opportunity Phase of the project. Much of their tacit knowledge transfer is in the form of guiding tacit knowledge and technical tacit knowledge.
- **Product Line Management Prime(PLM) - referred also as Project Product Line Management:** This individual is responsible for setting the product requirements. These individuals often rely on the extended functional PLM team to provide both the services and technical knowledge needed to technically define the product–tacit knowledge transfer therefore happens both to and from Project PLM to functional PLM. Project PLM works quite closely with the customer to define the product, as such it is their responsibility to choose the Lead Customer, this is done by negotiation with the Account Team. This individual is also responsible for ensuring that the product is finished and delivered on time. There is often ongoing two way transfer of tacit knowledge between Project PLM and the Account Teams as well to facilitate a seamless delivery process. This individual is also responsible for forecasting customer demands and then feeding this information to Manufacturing so that Manufacturing can forecast the amount of materials required for volume production.
- **Customer Support Prime:** This individual is responsible for managing the alpha and beta trials¹⁵ with the lead customer and ensuring integration of the customers' feedback into the development process. Often this knowledge transfer process is a tacit knowledge transfer process based on observations from customer interaction with the prototype.
- **Quality and Assurance Prime:** This individual is responsible for managing the software testing and verification of the product and reporting back on progress of this process to the core team and also ensuring project completion on time. Guiding tacit and technical tacit are the predominant types of knowledge transfer from this individual.
- **Manufacturing Prime:** This individual is responsible for the transfer of various project details between the core team and manufacturing, details concerning the manufacturing of the prototype, the forecast of materials, and volume production and delivery issues. Of principal importance to this individual is their contribution toward the efficiency and effective

15

Alpha and Bets Trials - Testing the product with the customer.

- delivery of the product to the customer. Technical tacit knowledge on the new product is often transferred from this individual to production.
- **Quality and Assurance Manufacturing Prime:** This individual is responsible for ensuring that certain standards and guidelines for product quality are adhered to during the manufacturing of the product. This individual is not on the core team for the full development cycle.
- **Marketing Prime:** This individual is responsible for putting out presentation packages, sales collaterals and trade shows documents for the product. She/he also works with PLM in providing customer information and informing and training the sales force about the product and its features.
- **Finance Prime:** This individual is responsible for the initial financial analysis on the product development initiative and maintaining the financial status of the project throughout the development cycle.

These people are all mutually accountable for the project success and are responsible for representing and managing the extended functional teams.

Because of the co-location of the core team, much of the knowledge sharing and tacit knowledge transfer occurs informally through ongoing face to face contact. Although, there are some suggested avenues for formal knowledge development and transfer, they are weekly core team meetings, business decision point meetings and knowledge transfer from the customer at key phases in the development life cycle described as alpha and beta intervals.

A Closer Look at the NPD Processes of Tel-Co

Phase 1: Idea - Tel-Co has several sources which help to foster the incubation and development of new product ideas. These are listed below.

Idea generation sources:

- **Senior person in charge of all investments:** This individual is continually looking at where to invest strategically and looking at new product ideas that may fall in line with the strategic direction of the company as a whole.
- **Technology Business Group:** This group is responsible for analyzing new market segments and new product possibilities that fall in line with these segments.
- **Disruptive Technology Group -** This group is responsible for analyzing new products that

- compete with current and potential future developments in the market.
- Within each business line, several individuals are responsible for the ongoing analysis of new product ideas.
- Within functional divisions, several individuals are responsible for the ongoing analysis of new product ideas.

A product concept is usually initiated from one of the areas above. The product concept is pulled together further during this phase by the Opportunity Team. The Opportunity Team consists of a two to three people, typically from the areas of marketing and engineering.

The Opportunity Team prepares a business case and a high level overview of the main technical elements of the product. Their work is highly iterative and interactive with one another. When the business case is completed, it is reviewed and evaluated by the Senior Portfolio Management Team (SMT)¹⁶ who reviews the business case based on the product's market opportunity and strategic fit with company objectives. If the product concept looks attractive based on these elements then the next phase of the development process, the Opportunity Phase, is funded. This Opportunity Team transitions to the core team if the product development process continues.

Phase 2: Opportunity - In this phase the Opportunity Team evaluates and outlines in further detail the product and its target market for example, identifying current and future market segments, current and future competitive landscapes, and establishing high level technical and market requirements, are parts of this analysis. The analysis also focuses on how the new product

16

Senior Portfolio Management Team - A senior management team and investment board, with the authority and accountability for setting strategy, initiating projects, and setting market based targets for projects that are funded from phase to phase. This team is comprised of highly experienced and senior individuals with in the firm from the areas of marketing, portfolio management, finance, operations, engineering, technology business practice and customer service.

may be differentiated from other current and future competing products. The majority of tacit knowledge transfer requirements come from marketing and PLM in this phase. The first contact with the lead customer¹⁷ is also usually initiated during this phase. The length of this phase is approximately six to eight weeks in duration.

Phase 3: Definition - Before a larger amount of money is committed to continued product development an overall assessment must be made if the product will be profitable and if the resources used will make the best use of the company's time and manpower. The core team comes together during this phase to complete the business case, the product requirements and the project plan. The business case will identify in part the minimal viable product features necessary to create a winning product. A good deal of reflection and tacit knowledge transfer occurs between this cross functional core team before these details are finalized. The length of this phase is approximately three to four months in duration.

Phase 4 - Implementation Phase: The objective of this phase is to develop the product from the prototype design. Extended functional groups accomplish the development, testing and integration of the hardware and software components. Knowledge on these areas is transferred from these functional teams back to the primary contact on the core team. The customer's feedback continues to be transferred through the PLM and the Customer Support Prime into the ongoing development process. Also developed during this phase are the production and materials plan, marketing and sales plans, customer support service plans, and customer documentation and training manuals. This phase is approximately one and a half years to two years in length.

17

Lead Customer - A company who works with the Opportunity and Core Team members to provide customer feedback on the product at each phase of development. During the Opportunity Phase the Leader Customer provides input on high level customer requirements.

Phase 5 - Deployment Phase: The main objective of this phase is to complete acceptance testing of the product and to prepare for volume production. Other objectives of this phase are to implement the sales and marketing plans, implement the support and service plans and complete the sales training and product documentation. This phase is approximately three months in length.

Phase 6 - Production Phase: The main activity of this phase is the volume production of the product. The core team involvement comes to an end during this phase. They prepare to hand off the product and transfer all product related knowledge to the Product Life Cycle Team, responsible for the continued improvement and support of the product until it is retired. Both the marketing and the PLM prime may transition from the core team to the Product Life Cycle Team. This ensures that there is access to the tacit elements of important product knowledge. The performance of the product also begins to be monitored and evaluated against the business case developed in the previous phase.

Mechanisms of Vertical and Horizontal Tacit Knowledge Transfer at Tel-Co:

Several mechanisms for tacit knowledge transfer can be detected at Tel-Co, they have been classified under vertical and horizontal tacit knowledge transfer (see page 75 for definitions of vertical and horizontal tacit knowledge transfer).

Mechanisms of Vertical Tacit Knowledge Transfer:

- **Use of the Cross Functional Core Team Structure:** vertical tacit knowledge transfer is facilitated during NPD because of the use of the core team approach and established knowledge linkages that facilitate tacit knowledge transfer from the core team to the functional teams.

- ▶ **Weekly Core Team Meetings:** These meetings are conducted in an open boardroom. They are conducted in the open for two reasons, other employees working on the same project will over hear the meeting conversations and recognize that business is being taken care of and secondly, the openness of the meetings allows those that are in the vicinity of the meeting to interject and make corrections (this is encouraged). The weekly meetings provide an opportunity for vertical tacit knowledge transfer between core team members and for other NPD members, "The open boardroom concept provides a second informal value for releasing knowledge and allowing for real time input from others in the area involved in the NPD initiative."
- ▶ **Off Sight meetings:** These meetings are used to guide and direct the core team. Role playing, story telling and guiding visions are the tools that are used to tacitly guide the efforts of the core team.
- ▶ **Co-location of the Core Team Members:** Members of the core team are co-located. The cubicles are spacious which provides a feeling of openness. Because of the co-location aspect, much of the knowledge sharing and transfer occurs frequently, informally and face to face throughout the development process.
- ▶ **Social functions between Core Team and customers:** BBQ's were used as a fun venue to informally transfer tacit knowledge between the customers, members of the core team and extended functional teams.
- ▶ **Established Links between the Core Team and the Lead Customer:** The NPD structure used by Tel-Co suggests several points of contact between the customer and the core team at various points in the development process.
- ▶ **Tacit Knowledge Transfer within the Core Team:** The core team often made use of interesting visuals, anecdotes, storytelling and key words to transfer tacitly product

knowledge and product management knowledge.

Mechanisms of Horizontal Tacit Knowledge Transfer:

- ▶ **Lunch and Learns:** Speakers from outside the company come and present and hold discussions on new technologies. These presentations and discussions act as a catalyst to effectively transfer tacit knowledge on other products and technologies.
- ▶ **Intergroup Presentations:** Held every couple of months, these presentations provide a venue in which product developers can present on NPD lessons learned. After the presentation, dialogue, examples and storytelling reinforces the tacit transfer of lessons learned.
- ▶ **Shop Talk Meetings:** Held monthly, these discussions allow for the transfer of explicit and tacit knowledge on different types of technologies.
- ▶ **Project Leader Meetings -** Project leaders get together to discuss issues related to the project leader position. These meetings are an important source of tacit knowledge transfer on project leader effectiveness.
- ▶ **Product Line Management Staff Meetings -** Product Line Management employees get together to discuss issues related to the PLM. These meetings are an important source of tacit knowledge transfer on PLM effectiveness.
- ▶ **An informal mentoring or buddy system** is often used within various technical groups to pass on technical know-how.

5.2 Exploration and Proposition Examination

5.2.1 Proposition 1: The Temporal Nature of Tacit Knowledge

The percent of tacit and explicit knowledge use, and the percent of contextual and technical tacit knowledge use was examined at all NPD phases for each company. What was expected from this examination in the three firms, is a pattern of explicit and tacit knowledge use, and a pattern of contextual and technical tacit knowledge use similar to what has been outlined in Hypothesis 1.

Figure 9: Proposed Relative Emphasis on Tacit and Explicit Knowledge Through NPD Phases

Figure 10: Proposed Relative Emphasis on Contextual Tacit and Technical Tacit Knowledge Through NPD Phases

Proposition 1a, the temporal model proposes that at the beginning to mid phases of new product development the need is more for the transfer of tacit knowledge, and at the mid to end phases of new product development the need is more for the transfer of explicit knowledge.

Proposition 1b, with respect to tacit knowledge needs at each phase, the temporal model proposes that at the beginning and end phases of NPD the need is more for the transfer of contextual tacit knowledge, and at the mid phases of NPD the need is more for the transfer of technical tacit knowledge.

Recall that contextual tacit refers to tacit knowledge pertaining to the customer, competition,

market segments, channels of distribution, sales and promotion, and project management and planning. Recall that technical tacit knowledge refers to tacit knowledge pertaining to the technical design, development, testing and verification, and the manufacturing of the product.

The aggregate results show that there is clear support for proposition 1a, but no clear support or negation of proposition 1b. Tel-Co supported hypothesis 1b, Soft-Co and Comm-Co did not. These differences appear to be company and context specific.

With respect to the breakdown of tacit and explicit knowledge use at each phase, all three companies use more tacit knowledge in the first three phases and less tacit knowledge in the last three phases of NPD. This finding was not surprising since the first three phases of any new product development effort are predominantly product innovation and design phases which require the use of larger amounts of tacit knowledge in the beginning but then requires less as the product concept moves from a tacit form (in people's heads) to an explicit, documented form along the NPD cycle.

However, there were differences among the three companies with respect to the amount of tacit and explicit knowledge used at each phase. Soft-Co used more tacit knowledge throughout many of the NPD phases than Comm-Co and Tel-Co. Tel-Co used the least amount of tacit knowledge during all phases. These differences can be attributed to two main reasons. Soft-Co used little process and when developing new products, they relied more on expertise (tacit knowledge transfer) from senior engineers throughout NPD; Tel-Co used NPD standards, and formalized NPD processes and roles (explicitly defined) which guide their development process.

Idea Generation Phase: phase 1 of the temporal model describes an idea generation process that uses more contextual tacit knowledge than technical tacit knowledge. In new product idea generation terms this would describe the evolution of product ideas mainly through greater marketing (contextual tacit knowledge transfer).

New product ideas in Tel-Co appear to be largely influenced through goals and input from the marketing side. In Soft-Co and Comm-Co, new product ideas are driven mainly through the development side of the organization. Soft-Co developed many of its ideas through senior engineers (technical tacit knowledge transfer) and Comm-Co developed many of its ideas through R&D. The tacit knowledge transfer and transformation for new product ideas at Comm-Co were supported more at the R&D level through the Strategic Technology Team¹⁸. See appendix B for more details on tacit and explicit knowledge use and contextual and technical tacit knowledge use at all companies.

Concept Analysis Phase: phase two of the NPD process involves analysis of the targeted market segment, comparing and contrasting the product concept with other competing products, and analyzing the technical feasibility of the product concept. Phase two of the temporal model describes a product concept analysis process that uses larger amounts of contextual tacit and less technical tacit. This typically reflects an investigation and analysis process that emphasizes marketing input, hence, greater emphasis is placed on marketing input and analysis (tacit

18

Strategic Technology Team: this team liaises with the academic community and government research organizations (ie. NRC, CITO, OCRI) with the intention of bringing back ideas, new product ideas and new R & D tools. The strategic technology group will then transfer this knowledge (tacitly and explicitly) through demonstrations of the prototypes or R & D tools to R & D groups in the company. Between five and ten percent of the ideas brought forth by the strategic technology group are used. This group is also responsible for attending external conferences with the purpose of bringing back new ideas. They also develop internal conferences with the purpose of sharing and generating new ideas within the company. Much of their tacit knowledge transfer is accomplished through prototype demonstrations.

knowledge transfer from marketing) to measure and assess the viability of the product concept.

Both Comm-Co and Tel-Co's concept analysis process reflect phase two of the temporal model, Soft-Co does not. In Tel-Co, further investigation into the product concept is accomplished through a business case analysis, where the business case appears to be driven by a comprehensive marketing analysis with larger tacit knowledge input from Marketing, Product Line Management and the customer. Comm-Co also conducts a feasibility study that assesses the viability of the product concept predominately through a case based largely on a process of marketing feedback (contextual tacit knowledge).

Soft-Co on the other hand seems to place more emphasis on the technical analysis during Concept Analysis. This is most likely due to the type of development process used by Soft-Co. They use a software development process that is similar to the Prototyping Model of development¹⁹. The first two phases of the Prototyping Model of development focus predominantly on developing a simplified version of the product prototype to investigate the product concept further. Much technical tacit knowledge is transferred or used to develop this prototype version and write code to support it.

Product Definition Phase: the third phase of the temporal model proposes that both contextual and technical tacit knowledge are equally important to the task of further defining the product before serious product development begins. Both Comm-Co and Tel-Co reflect phase three of the temporal model. Soft-Co does not, it tends to use more technical tacit knowledge during this phase.

19

When using the prototyping model for software development, the developer first builds a simplified version of the proposed system and presents it to the customer for consideration as part of the development process. The customer then provides feedback to the developer who goes back and refines the system requirements.

Phase three of the NPD process at Comm-Co and Tel-Co consists of creating a more thorough technical and marketing definition of the product. Comm-Co and Tel-Co put together a core team to validate and expand the assumptions put forth earlier in phase two to accomplish this task. Both of these companies stress the equal importance of technical and market definitions in this process. Much of this validation and expansion process is also completed through some explicit knowledge, but more tacit input.

Phase three in Soft-Co also consists of expanding the product definition, but the completed product definition is again accomplished through more iterative design and user product feedback that focuses on establishing more robust specifications for the expanded product definition. This is a process of greater technical tacit knowledge input requested in this phase.

Development Phase: all three companies reflect phase four of the temporal model. The fourth phase of the temporal model reflects a situation where mainly technical tacit is used to complete the tasks of developing, integrating product pieces and testing and verifying the product. Many of the activities at this phase are guided and influenced by explicitly defined project details prepared in previous phases, however, of the tacit knowledge that is used in this phase, the bulk of it is largely technical tacit know-how on product development, testing and verifying, and manufacturing processes.

Commercialization Phase: all three companies reflect phase five of the temporal model. The fifth phase of the temporal model reflects a situation where mainly contextual tacit is used to complete the commercialization of the new product. Although volume production is a large part of this phase, it is accomplished mainly through explicit (technical) knowledge, predefined manufacturing plans

and processes designed in previous phases. The majority of tacit knowledge used in this phase is mainly contextual tacit knowledge required to prepare and implement marketing, sales, after sales service and to transition the product to the next team for the continued product improvement process.

In summary, the substantial differences in contextual and technical tacit knowledge use among the three companies are found in the idea generation and the concept analysis phase. As can be seen from the results of this examination idea generation is a process that can be driven from the development or marketing side of the organization, or both. Each of course would require the input of very different types of tacit knowledge and would presumably steer the development process in different directions. Our findings show that concepts are also validated differently (phase two), some by assessing its technical feasibility (completed through larger amounts of tacit knowledge transfer and input), others by assessing its market feasibility (completed through larger amounts of contextual tacit knowledge input and transfer).

Also the results from this analysis show that the Prototyping Model of software development used by Soft-Co uses larger amounts of technical tacit knowledge in the initial development phases than the Pace Model used by Comm-Co and the Time to Market Model used by Tel-Co which focus predominantly on the transfer of contextual tacit–marketing input and feedback in the initial development phases.

5.2.2 Exploring How the Transfer and Transformation of Tacit Knowledge Occur in NPD

Here we explore by whom, and how the transfer and transformation of tacit knowledge occurs in NPD. Qualitative analysis was applied to the interview narratives of each company. In each company's narratives we examined the number and composition of NPD teams and how the transfer and transformation of tacit knowledge occurs within and between these teams. The aggregate results of this analysis in Soft-Co, Comm-Co and Tel-Co follow. See appendix B for a detailed analysis in this area for each company.

Examining the Composition of NPD Teams Engaged in Tacit Knowledge Transfer and Transformation Processes

We said earlier that transforming the product idea from concept to the first documented design to the final product, requires many iterative processes of tacit knowledge transfer and transformation. In an NPD setting these development activities are achieved with teams. In many companies multiple teams are involved along the NPD cycle. But whether a company uses one team or more, the senders and recipients of tacit knowledge transfer and transformation are principally individuals within the same team who are required to build on (tacit knowledge transformation) the input of others (tacit knowledge transfer) within the team to achieve the objectives of the team. Although, in multiple team contexts inter-team knowledge transfer can also occur, however our findings show that knowledge exchange between NPD teams tends to be more explicit knowledge exchange.

What we describe below is the number and type of teams that are used in NPD. We describe some of the members of these teams and describe whether the knowledge transfer process between them, is explicit or tacit.

All three companies use the *core team approach*²⁰ to make decisions and manage the principal development activities that occur, however the composition and role of the core team differ slightly among the three companies. As well, Comm-Co and Tel-Co who also use *extended functional teams*²¹ in NPD have also created different types and levels of knowledge transfer linkages between the core team and extended functional teams. These linkages are discussed next under *examining how the transfer and transformation of tacit knowledge occurs in NPD*. Also, the composition of the core team at Soft-Co is fairly homogeneous next to that of Comm-Co and Tel-Co. Later in this chapter we also review core team heterogeneity and homogeneity and analyze its effect on the tacit knowledge transfer and transformation process within these teams.

Soft-Co used two principal teams in their NPD process. The first team, the core team, which was responsible for design activities and for managing the integration of other NPD activities, is typically consisting of senior developers, architects and product management. The second team is responsible for product development and testing and verification activities. Each team consists of approximately 30 people. Soft-Co is a software company, therefore no manufacturing activities exist. Knowledge transfer between the two teams occurred both explicitly and tacitly, through many face to face meetings between the two teams.

20

Core Team Approach: With the core team approach, a cross functional team is formed and used to make the principal development decisions and manage extended functional team involvement during the development of the new product. Knowledge transfer between NPD phases tend to be more seamless with the core team approach than with the functional project approach which has been described as a "throw it over the wall environment" often leading to the discontinuity of knowledge between phases.

21

Extended Functional teams - design, development, quality and assurance, manufacturing and marketing functions often represent functional teams that are required to develop certain NPD elements. These teams are not a part of the core NPD team but are recognized as necessary functions needed to complete aspects of the product before it gets launched. Because of their importance to the NPD process, these teams are typically called extended functional teams.

Two teams at Tel-Co and Comm-Co are responsible for establishing the product concept, expanding it and bringing it to the first level documented design or prototype. The first team in this process at Comm-Co and Tel-Co, called the Concept and Opportunity Team respectively, are usually consisting of three or four senior people from the engineering and the marketing discipline. These teams present a preliminary analysis of the product concept. The second team involved in this process at Comm-Co and Tel-Co, the core team, is responsible for validating the assumptions made in the analysis by the first team and also for defining further the technical and market requirements of the product before serious development begins. As we pointed out before they are also responsible for making the principle development decisions in NPD and managing extended functional team involvement throughout the remaining NPD process.

In Tel-Co, a member from the Opportunity Team usually transitions to the core team so that the opportunity exists to transfer the tacit knowledge of the Opportunity Team to the core team. Comm-Co does not always transition members from the Concept Team to the core team, however they did state that members of the Concept Team tend to be excellent communicators and that they conduct several face to face meetings to ensure that the transfer of product issues and details not yet explicitly defined would be achieved.

Comm-Co develops their core team with members from engineering, product line management, product supply, marketing, sales and regional support. Members of the core team at Comm-Co, typically remain on the core team until development of the product is complete. Tel-Co develops their NPD core team with members from development, product line management, quality and assurance, operations, marketing, finance and global customer support. Unlike that of Comm-Co, Tel-Co has an individual on the core team who represents finance and quality and assurance, but

does not have an individual representing sales. Also, unlike Soft-Co and Comm-Co, the core team members in Tel-Co exist principally to manage the development process. Execution of the development occurs only through extended functional teams. Tel-Co also fundamentally believes that core team members should not change until the development of the product is complete. In fact, this aspect of team composition is an integral part of their NPD framework, they believe it ensures the continuity of product knowledge that is not yet explicitly defined.

In summary, all three companies have employed different strategies for NPD team composition. The number of NPD teams used, the composition of each team and how knowledge is transferred between NPD teams differs among the three companies.

Our findings will later demonstrate that team composition (level of heterogeneity and homogeneity) will affect the transfer and transformation process within a team (to be discussed later in this chapter). But also the number of NPD teams used in an NPD process, whether tacit or explicit or both knowledge types are transferred between these teams, and whether a team members' carries on from one team to the next team, will also ultimately affect how effectively and efficiently NPD knowledge flows between phases and whether there is more potential for knowledge continuity or discontinuity between phases. For example, Tel-Co believes that employing a two-team NPD strategy may potentially disrupt the continuity of product knowledge unless a team member carries on from the first team to the second team.

Examining How the Transfer and transformation of Tacit Knowledge Occurs in NPD

The transfer of tacit knowledge was described as a process of externalizing and sharing tacit knowledge, and the transformation of tacit knowledge as a process of using tacit knowledge to build

or amplify other tacit or explicit knowledge. Externalization and amplification are done through many types of communication media. The communication media that are used in these processes at each company are outlined below.

First, recall that tacit knowledge externalization is described as the conversion of tacit knowledge into comprehensible forms. Nonaka and Konno (1998) have argued that tacit knowledge is effectively articulated through figurative expressions such as metaphors, analogies, narratives and story telling. Leonard and Sensiper (1998) have discussed drawing and prototyping as valuable ways of externalizing tacit knowledge in product development environments.

Interviews with product designers and developers in all companies show that the same externalization tools²² are used for design and development processes, such as case maps, computer aided drawing tools, flow charting and prototyping. However, outside the design and development functions the use of externalization tools (storytelling, anecdotes, examples, role playing) to externalize contextual tacit knowledge by Tel-Co differs from Soft-Co and Com-Co. For example, the project leader of an NPD project at Tel-Co made greater use of externalization techniques when managing and guiding the core team. During the initial development of the core team the project leader made arrangements for many off site meetings. During these meetings the project leader used analogies, story telling and role playing (Leonard and Sensiper (1998) describe these methods as an effective way to communicate tacit knowledge) to create team alignment, accountability and a better understanding the project responsibilities. The core team at Tel-Co also created a team logo and mission and vision statements. Leonard and Sensiper (1998) describe

22

Leonard and Sensiper (1998) state that two externalization tools effective for design and development are drawing, prototyping and other types of drawing tools.

these externalization tools as forms of guiding tacit knowledge. They suggest that these methods are extremely useful when trying to communicate or externalize project expectations or guidelines that are often more tacit in nature.

All companies use a combination of communication mediums to achieve the processes of tacit knowledge amplification, they are face to face, e-mail, and telephone. Of the three mediums listed above face to face communication is by far the most predominant form used by all three companies.

All companies try to achieve as much face to face interaction as possible among members of the core team, and within and between functional teams. While all three companies suggest that face to face interaction is by far their most successful way to achieve the transfer and transformation of tacit knowledge, they have employed different types of face to face communication strategies.

All three companies believe in and employ where possible the co-location²³ of team members to achieve frequent and informal face to face interaction. Face to face interaction is easily achieved by Soft-Co. The employees of Soft-Co are situated in one building, with the hub of new product development located in one area of the building. Hence, the co-location of more than one new project in this area also offers the added advantage of tacit knowledge transfer between new projects. The office design is a combination of enclosed offices and cubicles. With respect to the development teams at Soft-Co, development and quality and assurance for NPD are a part of the same team. One engineer who performs development activities sits next to another team member who performs verification activities. Compared to Comm-Co and Tel-Co, Soft-Co relies more on the co-location of employees to achieve the majority of their tacit knowledge transfer needs. Soft-Co

23

Recall that co-location refers to the idea of physically placing members of a team next to each other.

has an unstructured new product development process, however some regularly scheduled meetings do exist that provide for more formal methods of tacit knowledge transfer, they are weekly core team meetings, quarterly meetings and code reviews (see Descriptive Data, Chapter Five, Vertical Tacit Knowledge Transfer).

Comm-Co and Tel-Co use a combination of formal and informal face to face strategies to achieve their tacit knowledge transfer needs. Both companies co-locate most of the members of their core team, although Tel-Co co-locates their manufacturing and marketing prime in two places, with both the functional and the core team. The office design of Comm-Co is a combination of offices and cubicles. Tel-Co's office design consists of cubicles only. The cubicles are quite large providing a feeling of openness. Tel-Co has an open board room concept, where the core team conducts their weekly team meetings in the open. The project leader of Tel-Co stated that the weekly core team meetings are conducted in the open so that co-located NPD functional team members can over hear issues being discussed and communicate corrections to the core team when necessary.

Tel-Co has more formal knowledge transfer links in place than Comm-Co. Both companies have weekly core team and phase review meetings. However, Tel-Co's NPD process recommends more formal points of contact for knowledge transfer from the lead customer at various points in the NPD process (Chapter Five Descriptive Data, Vertical Tacit Knowledge Transfer).

Different strategies/methods exist with respect to tacit knowledge transfer among core team members. Whether these methods are unconscious or conscious, the method employed at each company (as described above) will ultimately affect the ease and success with which tacit

knowledge is transferred.

5.2.3 Exploring Problems and Barriers to the Effective Transfer and Transformation of Tacit Knowledge

This area examines common problems and barriers to the effective transfer and transformation of tacit knowledge. We focus on issues that account for why the transfer and transformation process might not go the way one would hope. We also look at the types of tacit knowledge that are typically not transferred into NPD, but are argued to be important to those interviewed. The most common issues among the three companies found in this analysis are outlined below. We also present the most common problem specific to each company. All other details from this analysis are outlined in table format under Appendix B.

The findings from this analysis show that the three companies share several common issues that can be categorized under the following areas: problems with the tacit knowledge externalization and/or amplification processes among NPD team members, insufficient or poorly documented new product design and development knowledge during the NPD process, and the insufficient transfer of tacit knowledge between NPD teams. These problems result in slower time to market, missing customer requirements in product design, developing a product for which there is no market, decreased quality in after sales customer service and difficulties with the next generation product due to a lack of documented new product knowledge.

5.2.3.1 Tacit Knowledge Transfer and Transformation Problems/Difficulties Common to Soft-Co, Comm-Co and Tel-Co

A. Problems with the Tacit Knowledge Externalization and Amplification Processes among NPD Team Members

Difficulty in externalizing tacit knowledge within a heterogeneous team: Both Comm-Co and Tel-Co use the cross functional core team approach to make primary development decisions and manage the development of the product across functional boundaries. Although both companies believe that the core team approach is critical to successfully coordinating NPD activities across functional boundaries, several core team members in each of these companies also acknowledged the communication difficulties that exist in a team consisting of members from different functional backgrounds.

Several interviewees commented that incorrect assumptions are often made between members from different functional backgrounds, and that this problem appears to be more serious at phase two when the high level definitions of the product are being determined by members of the core team. Communication difficulties were also described between team members with gender, large age and language differences. Soft-Co did not describe this as an issue, however their core team appears to be much more homogenous than that at Comm-Co and Tel-Co. There is also some speculation from some interviewees that the homogenous nature of their core team (lack of cross functional involvement) may have led to the development of some products for which there was no market. Recall from the literature review, Pelled (1996) and Leonard and Sensiper (1998) discuss the difficulties of converting and transferring tacit knowledge in a team with highly visible differences. Pelled argued that tacit knowledge is not heard as much in groups where differences are readily observable. Although tacit knowledge externalization difficulties may be minimized in a more homogeneous team, knowledge amplification effectiveness may be hindered. Janis (1982) also argues that homogeneous teams are often subject to group think, a comfortable common view point leading to close mindedness and pressures toward uniformity.

Difficulty externalizing and amplifying tacit knowledge through an electronic communication medium: Knowledge breakdowns²⁴ were reported to have occurred in Comm-Co and Tel-Co when electronic mail was used too often in the initial NPD phases where a greater degree of tacit knowledge transfer and transformation is required. Recall from the findings that the predominant periods of tacit knowledge transfer and transformation occur in phases one to three because the product concept requires many sessions of tacit knowledge transfer and transformation between team members before the first level design of the product is ironed out.

E-mail is a useful medium of communication between members, but in conditions where there is a greater degree of tacit knowledge transfer and transformation, greater face to face interaction would ensure more effective knowledge transfer between team members. In the literature review, Lave and Wenger (1991) argue that interactions during which the parties are not physically co-present, such as e-mail and telephone conversations, exclude meaningful sensory information and context which are necessary for an accurate perception and understanding of what is going on.

Soft-Co did not describe knowledge breakdowns during the first three phases, however frequent face to face communication is their main source of communication during high periods of knowledge building and problem solving during the design phase. Soft-Co also designed mouse pads that outlined in a humorous way the danger and drawback of communicating too much through e-mail. Finholt and al. (1990) also observed that software development teams use e-mail for coordinative tasks but on the whole they prefer interacting face to face for problem solving.

B. Insufficient and/or Poor Documentation of New Product Design or Development Knowledge

Insufficient and/or poor new product documentation during the design and development process:

All companies commented that there was often a lack of, or poor design and/or development documentation in NPD. Soft-Co described poor product documentation as often leading to the need to reinvent product solutions during second generation product development. Tel-Co described the need for live a document tool to facilitate the documentation process. They described the documentation process as being time consuming and difficult. They argue that less tacit new product knowledge would be lost if live documentation existed to record new design additions, changes, and also allowed for the input of the rationale behind these additions and changes. Comm-Co also commented on the benefit of having some sort of live document to facilitate documenting the thinking processes behind new product design and development choices.

Soft-Co described difficulties with documenting design knowledge. They described the source of this problem as being a lack of documentation standards. They commented that the lack of good documentation standards makes the interpretation of existing design code difficult and makes the sharing of design knowledge between new product projects difficult. Recall from the literature review that Ramesh and Tiwana (1999) describe one of the most prevalent problems in NPD as being the lack of codified design and development tacit knowledge. Their research examines important elements of a live documentation product that will help to reduce the loss of tacit new product knowledge throughout the NPD process.

C. Insufficient Transfer of Tacit Knowledge

Lack of tacit knowledge transferred and integrated from the customer during the design process:

Comm-Co and Soft-Co describe this problem as being one of the more serious problems in NPD.

Interviewees at Comm-Co made the following comments, "there is a need for the customer voice to be inside our R and D activities," "a greater need exists to understand first hand in R & D what the customer needs," "what would be ideal is to have the customer sit in with the NPD team when they are developing the product" and, "we are beginning to get the customer in earlier in the NPD process but this has to happen more frequently." As a result of the lack of this type of tacit knowledge embodiment in the early product design and development phases, some new products at Comm-Co may have been short on important customer specifications.

Interviewees at Soft-Co also made similar comments, "there is a tendency to integrate marketing, the customer and field support too late into the NPD process, "; " There is a need for the development organization to understand how to look for software solutions that solve particular business problems. This requires more effort to understand first hand customer processes and problems," "there is a need for greater customer involvement in the testing and verification environment" and, "the Quality and Assurance business analysis often falls short because of this lack of customer involvement." As a result of the lack of this type of tacit knowledge integrated into the development process, some new products were developed at Soft-Co for which there was no market.

Tel-Co did not describe this issue as being a problem because their NPD structure and processes already place importance on integrating customer feedback early on in the design and development and throughout NPD. The development process of Tel-Co is described as being built on *rapid customer engagement*²⁵. The primary responsibility of one of the members of the core

25

Rapid customer engagement - The development of the product occurs in incremental alpha, beta development steps. At each incremental development step customer feedback is initiated and integrated back into the development of the product. Alpha refers to the process of engaging the customer early on in the development process with the purpose

team at Tel-Co is to manage the relationship with the lead customer and ensure that a steady flow of customer/user feedback is integrated into the new product development process.

Insufficient tacit knowledge transfer with the transfer of explicit documents: The transfer of explicit documents between teams are often described in NPD as being “thrown over the wall.” All companies described situations of knowledge breakdown between teams where explicit information was the only source of knowledge transfer. New product knowledge is rich in know-how, intuition and judgement that often needs to be transferred between teams in NPD, but can only be expressed through tacit knowledge transfer (Nonaka and Takeuchi, 1995). Tacit knowledge transfer links are needed to ensure its transfer among team members and between teams.

Tel-Co and Soft-Co described this phenomenon as being quite common to their NPD environments but also described it as having serious implications to the outcome of various NPD activities. For example, at the end of the Tel-Co’s NPD process, new product information is transferred from the core team to the Product Life Cycle Team -- a team that supports continuous improvement of the product through out the remaining life of the product. This hand off process is accomplished through the transfer of explicit knowledge between these two teams. The Product Life Cycle Team stated that they are often short on new product knowledge or know-how after the hand off process to provide adequate quality of after sales service to customers.

Comm-Co suggests that if team members transition from the NPD team to the continuous improvement team then this problem can be minimized. Soft-Co also suggests that this problem

of understanding of customer needs and also clarifying the product definition with respect to the customer solution early on. Beta refers to obtaining customer feedback on the robustness of the product.

can be further alleviated by having authors of key documents present and be available for a question and answer period to avoid the misinterpretation that can often be accompanied by the transfer of explicit knowledge between teams in NPD. This issue highlights the need for methods that effectively transfer the tacit component of NPD knowledge along with the transfer of explicit documents between teams.

Lack of tacit knowledge transfer between new project teams and independent technology groups: All companies described a lack of tacit knowledge transfer between project groups. Tel-Co described a need to transfer more tacit knowledge between new product development projects, knowledge about lessons learned and best practices. They feel that this would be best achieved through knowledge sharing forums where project members can learn from each other by sharing success stories and failures.

5.2.3.2 Case Studies - Tacit Knowledge Transfer and Transformation Issues

We also found problems specific to each case study, they are presented below.

Case Study - Comm-Co: The most commonly described problem at Comm-Co relating to the transfer of tacit knowledge was described as the insufficient transfer of tacit knowledge from the product user during design and development activities. Because the product concept is new, there is often little information and knowledge on the needs of the user, therefore feedback from the product user is critical. Feedback transferred from the user to marketing and then to design and development can often lose its meaning.

Some less successful products at Comm-Co were described as missing important consumer features as a result of this lack of tacit knowledge transfer. Historically this type of knowledge has

been transferred from the product user to marketing and then to design and development at Comm-Co. There was some discussion at the time the interviews took place to potentially establish a direct link between the product user and R & D to ensure that effective tacit knowledge transfer (the meaning of the message is not lost) from the user was integrated into the design process. One interviewee suggested that if this type of knowledge is to come through marketing then marketing and design would need to establish a system to ensure that the continuity of tacit knowledge is maintained between the user, marketing and design. Another interviewee at Comm-Co gave examples that described the discontinuity of knowledge between marketing and design because the marketing person on the core team had changed several times during the NPD process.

Thus, a feedback system needs to be established between the product user, marketing and design and development to ensure that the tacit meaning of a message communicated by a product user is not lost among the three NPD functions. Von Krogh, Ichijo and Nonaka (2000) recommend direct interaction between the customer and the designer, "Prototypes can be shown to customers at an early stage to get their preliminary reactions to the design as well as to check out the market. The customer can be given some degree of freedom in operating the prototype while the designers watch his or her interaction. Service technicians are also natural participants in the prototype-creation phase since their input will enhance the serviceability of the end product."

Case Study - Tel-Co: The most commonly described problem at Tel-Co relating to the transfer and transformation of tacit knowledge was described as too much NPD process and structure in the beginning NPD phases. This appeared to impede the tacit transfer and transformation processes of the initial phases. Additionally, they describe too little NPD processes and structure during the latter phases of NPD which does not appear to take into account the proper transfer of important

explicit project details. They described too few quality control checkpoints.

One interviewee argued that too many project issues have to be referred back to the senior portfolio team or other organizational bodies outside the core team for approval before they can advance. He commented that these processes often impeded the innovation flow of product prototype design and development. Another interviewee also commented that too much project detail was required during the product concept investigation phase which impeded the flow of the design process. Recall from the literature review that Leonard and Sensiper (1998) discussed the difficulty of transferring and transforming tacit knowledge in an environment with too much structure. Von Krogh, Ichijo and Nonaka (2000) also describe an enabling structure for tacit knowledge transfer in NPD as one that enables the quality and depth of a participant's interactions.

Comments were also made which referred to there being too little process during the latter phases of NPD. Several interviewees described the need for more structure between design and manufacturing to ensure that the right knowledge and an adequate level of knowledge is transferred between these two functions. Recommendations were also made to increase the duration of face to face training between design and manufacturing from four days to two or three weeks to adequately transfer important and detailed project information often found in the later phases.

Another interviewee also described the need for more process (some sort of check list) during the prototype production before the product goes into volume production. He argued that when Tel-Co attempted to reduce the cycle time by decreasing the number of check points and gates, they may have been neglecting an important part of quality that is needed. "Structure is needed,

not with the outcome of delaying the project but with the outcome of ensuring quality.” Several interviewees also described the need for more structure between the core team and the Life Cycle Team. Comments were made that more processes and checklists are needed to ensure that the right knowledge and adequate levels of knowledge are transferred from the core team to the Life Cycle Team during the project “hand off “ period to ensure quality after sales customer service.

According to the examples outlined from Tel-Co interviewees, it appears that the NPD structure and processes of Tel-Co were not designed to take into the account tacit and explicit knowledge use and transfer at each phase. Less process/structure is recommended to enable the tacit knowledge transfer and transformation processes found mainly during the product innovation phases, one to three (Von Krogh, Ichijo and Nonaka; 2000), and more process/structure is recommended to ensure that detailed (explicit) product development and project plans are carried out and knowledge continuity is established between NPD teams.

Case Study - Soft-Co: The most common problem at Soft-Co relating to the transfer and transformation of tacit knowledge was described as the need for tacit knowledge transfer (feedback) from marketing and a need to standardize NPD processes and create more links to facilitate tacit knowledge transfer between NPD phases and NPD projects.

Several interviewees commented that marketing does not get involved in the new products process until a functional prototype has been developed half way through phase three, the prototyping phase. They also stated that there was possibly a correlation between the late integration and lack of marketing integration in the process, and the failure of certain new products to meet the needs of the market, for example some comments were, "what is needed is a senior

marketing person who really understands business intelligent markets, how to craft it up into pieces and how to define products to attack those portions of the market," "there is a tendency to bring in marketing, the customers and field support too late into the NPD process." Recall from discussions in the literature review (Von Krogh, Ichijo and Nonaka 2000) that other functions such as marketing, manufacturing and strategic planning should come into the process before serious prototype development begins. Experience, know how and intuition from other functional areas is needed for successful NPD planning and launch.

At Soft-Co interviewees also expressed needs for greater standardization of NPD processes. For example, there was an expressed need for creating standards for identifying markets for size and revenue and for documentation standards. As a result of a lack of documentation standards (standards for codifying tacit new product design and development knowledge) a "hodgepodge" of documentation processes exists at Soft-Co that make understanding existing code difficult and can make the sharing process between new projects difficult. In the latter phases of development, one interviewee commented that no standards exist between development and Q and A. He added that development typically used different coding practices than Q and A which made the testing and verification process difficult. Recall from the literature review that Hedlund and Nonaka (1993) argue that articulation, internalization and reflection of tacit knowledge are facilitated by the availability of shared mental models that represent the way a given organization works.

5.2.4 Exploring Factors that Enable the Tacit knowledge Transfer and Transformation Processes in NPD

In order of importance, as per interviewee feedback from the three companies, here we summarize the factors that enable the tacit knowledge transfer and transformation processes most

in NPD. All other findings related to each company for this analysis are outlined in Appendix B. Seven common factors were described as enabling the tacit knowledge transfer and transformation processes most in NPD: using the core team approach to develop new products, co-locating core team members, ensuring that the core team members remain the same throughout the NPD cycle, creating formalized NPD structure and process to facilitate knowledge linkages and knowledge transfer, creating ownership of NPD tasks, creating small teams--the core team and other functional teams in NPD, using project and team incentives, and ensuring that the project leader for the NPD initiative is optimistic and positive.

Using the core team approach to develop new products and ensuring that the core team members remain the same throughout the NPD Cycle: Recall that, the core team approach is described as a cross functional team, (typically with members from marketing, engineering, design, development, testing and verification and manufacturing) that is used to make the principal development decisions and manage extended functional team involvement. During discussions with each company, the core team approach was described as being essential to the efficient and effective transfer of tacit knowledge across functional divisions. The core team approach was often contrasted with the functional development approach in interviews, which was argued to foster a "throw it over the wall" project environment often leading to the discontinuity of knowledge between teams and phases.

The members of the core team typically come together in the second or third phase of NPD after the product concept has been investigated. Comm-Co pointed out that members of the core team should remain the same throughout the NPD cycle. They argued that this aspect of the core team approach supports one of the primary functions of the core team, which is to ensure the

continuity of project and product knowledge between phases and teams. Many interviewees at the three companies also argued that the core team approach to NPD enables better overall project communication, coordination and decision making.

Co-locating Core Team Members: The co-location of core team members was described as being another important factor to the success of the tacit knowledge transfer and transformation processes. All three companies co-locate their core team members. Functional members within the same functional team also appear to be co-located at the three companies. At Soft-Co and Comm-Co functional teams are also co-located on the same geographical premises. At Tel-Co, development and manufacturing are not co-located on the same geographical premises. Not surprisingly, knowledge transfer issues were reported to exist between these two functional groups because of this.

Tel-Co described the concept of leveraging the benefits of co-location further through office design. They argued that a team whose members are co-located in enclosed offices will not be privy to as much tacit knowledge transfer as members who are co-located in cubicles. Tel-Co has leveraged the benefits of co-location further by creating an open board room concept which is situated amongst the cubicles of the core team members. They describe conversations of the core team as being over heard by extended functional members of the team who are situated in the same area. One project leader at Tel-Co stated that, "the secret to effective knowledge transfer in NPD is to over communicate, and co-location provides for that possibility."

Creating formalized NPD structure and process to facilitate knowledge linkages and knowledge transfer in NPD: Comm-Co and Tel-Co argue that formalized NPD structure and processes are

necessary to enable and support tacit knowledge transfer and transformation during NPD. They argue that it also facilitates knowledge transfer consistency. In their NPD structure and processes, both Tel-Co and Comm-Co use the core team approach, a phase review process (kill/go decisions at defined specific NPD points) and specified knowledge linkages between the core team, extended functional teams and the client to create this knowledge transfer consistency and enable tacit knowledge transfer.

Creating ownership of NPD Tasks: Interviewees at the three companies stated that when NPD members are given ownership of and made accountable for certain tasks in NPD, the tacit knowledge transfer and receiving process are encouraged. At Soft-Co, an interviewee argued that an individual that is made accountable for certain tasks will also often feel the impetus to acquire knowledge first hand, and face to face, to ensure that the information has not been taken out of context or misinterpreted because they understand that with accountability they are ultimately responsible for the quality and completion of the task. At Comm-Co, another interviewee argued that giving accountability of tasks to individuals does not in itself ensure communication, but it gives them the motivation to get what they need to fulfill their responsibilities. One interviewee at Tel-Co commented that one method for making team members accountable for certain tasks is to get each member to sign a project agreement that will specify the roles and responsibilities of each project member. They also suggested that the project agreement should be reviewed periodically at various phases to reconfirm accountability and ownership of various tasks.

Creating Small Teams –The Core NPD Team and other Functional Teams in NPD: All three companies discussed the communication difficulties that exist using large teams to develop new products. They commented that large teams definitely hindered the tacit knowledge transfer and

transformation process. They argue that the communication process is naturally easier, more fluid and more effective in smaller teams. Research has also shown that small teams tend to communicate more face to face than larger teams (Finholt et al. 1990).

One NPD Project Leader at Soft-Co described a situation where the use of a very large team in one NPD initiative led to communication and management difficulties, which eventually resulted in the failure of the new product.

Comm-Co also breaks down the development of their product into product pieces so that small teams can perform development activities. They have suggested that a team of more than twenty people would have communication difficulties. One interviewee at Tel-Co also argued that core NPD teams should not be larger than eight people. He argued that there is not enough space for people to communicate within a core NPD team consisting of more than eight people, "I believe that groups of eight or less can make progress and groups of nine or more can have discussions. I can see how the tacit knowledge transfer and transformation process would be very difficult in teams that are too large."

Using Project and Team Incentives: Individuals interviewed in the three companies commented on the positive influence that project incentives have on the tacit knowledge transfer process in their teams. At the time the interviews took place in Comm-Co, the organization had changed from a compensation bonus system tied to company performance to a bonus system based on specific R & D objectives, including time to market development objectives for each NPD team. Comm-Co believes that this bonus system will motivate employees to share and transfer their tacit knowledge.

Tel-Co also believes that incentives play a large part in the motivation and speed with which knowledge is transferred and developed for NPD. At the time of the interviews, Tel-Co had a standard profit-sharing plan and also a time to market team-based bonus system for developing and delivering the new products on time according to various standards. They see this as a method to increase team collaboration and increase the sharing and transferring of tacit knowledge among team members in a more timely manner.

Ensuring that the project leader for the NPD project is optimistic and positive: Soft-Co and Tel-Co argue that ongoing positive leadership is needed to enable the tacit knowledge transfer and transformation process in NPD. Individuals interviewed in these companies state that many obstacles and challenges often arise during the development of a new product. They argue that optimistic and positive leadership is essential to support and encourage tacit knowledge transfer and transformation processes during these difficult periods.

5.2.5 Propositions 2a, b & 3: The Influence of Various Elements on the Tacit Knowledge Transfer and Transformation Processes within NPD Teams

To verify proposition 2a and 2b, we analyzed the degree of heterogeneous and homogeneous knowledge sets, and shared mental models within the core NPD teams and analyze these variables in conjunction with the team's ability to transfer and transform their tacit knowledge.

What was expected from this analysis is a pattern similar to that outlined in proposition 2a and b below:

Proposition 2a: The degree of heterogeneity (dissimilar knowledge sets) among the team will have

a curvilinear relationship (inverted U) with the effectiveness with which the team can transfer and transform its tacit knowledge. Heterogeneity within the core team refers to the composition of the team with members from diverse functional areas, such as engineering, marketing, sales, customer support and strategy.

Proposition 2b: The degree to which mental models within the team are shared will have a direct relationship with the ease and effectiveness with which the team can transfer and transform its tacit knowledge.

Verifying Proposition 2a: The case studies generally lend support for proposition 2a. Although there is support for this hypothesis it should be noted that is case-based research so these results should not be generalized to other firms engaged in NPD.

Comm-Co and Tel-Co develop NPD core teams that are fairly heterogeneous, that is, with members from many different disciplines/NPD functions. The core team at Comm-Co consists of seven to eight individuals from the areas of project management, engineering, product line management, product supply, marketing and sales. Similarly the core team at Tel-Co is also consisting of eight individuals from slightly different disciplines than Comm-Co, project management, development, testing and verification, product line management, customer support, manufacturing, marketing and finance.

Both companies believe in and depend on input (tacit knowledge transfer) from these diverse skill sets outlined above to develop the right product definition (tacit knowledge transformation) and to successfully manage the development of the project across functional boundaries. Their

experience has told them that successful new product development decisions are derived through the joint decision making of team members from these diverse functional areas of NPD. Differences between team members stimulate the "requisite variety" (Campbell, 1960) of ideas that permit focus on a wide array of actions and choices.

Although both companies acknowledge the benefits of the cross functional core team, communication difficulties and erroneous assumptions were commonly described between these team members. Tacit knowledge is not heard and valued as much in groups where there are readily observable differences (Pelled, 1996). These differences apply to function, educational background, age, gender and race. One interviewee at Comm-Co commented, "These people are from different disciplines, that is the strength of it but that is also the weakness of it. We are talking about information that does not get transferred. Someone will say something and she/he will assume that everyone understands. The other team members will assume they understand but really they will both be thinking something different. This situation occurs most often in high level product definitions."

In Soft-Co, core teams are mainly consisting of individuals with similar backgrounds (referred to as homogeneity). Soft-Co did not describe any communication difficulties with homogenous team composition, probably because tacit knowledge is easier to externalize between individuals with common understanding and similar backgrounds (Nonaka and Hedlund, 1993), however with homogeneous team composition, the team also runs the risk of being exposed to group think. Group think (Janis, 1972) is described as like-mindedness among members of the same team. Like-mindedness can be a barrier to exploring alternatives that are needed in NPD research. Several interviewees at Soft-Co did describe the development of new products for which there was

no market. There may be a correlation between the homogenous nature of their core team and the failure of these products.

Proposition 2a model suggests that although diverse knowledge sets among a cross functional core team may be beneficial toward the transformation of knowledge in NPD, team members may also have difficulties externalizing their tacit knowledge to each other. However, there are various externalization tools (referred to in Chapter Two) that may increase the effectiveness of the externalization process, even in a team with members from highly diverse and cross functional backgrounds.

We explored the effectiveness of the tacit knowledge transfer and transformation process in relation to core team levels of heterogeneity and homogeneity within each company, figure 11 presents these findings below.

Figure 11: Proposition 2a - The Degree of Heterogeneity within the Core Team and its Effect on the Team's Ability to Transfer and Transform Tacit Knowledge

Verifying Proposition 2b: The case studies generally lend support for hypothesis 2b. Although there is support for this hypothesis it should be noted that this is case-based research so these results should not be generalized to other firms engaged in NPD.

Shared mental models refers to similar memory bases of organizational experiences. Organizations are networks of inter-subjectively shared meanings, sustained by a common language (Burrell and Morgan, 1979; Daft and Weick, 1984; Walsh and Ungson, 1991) and that the availability of this common language will facilitate the transfer and transformation of tacit knowledge in organizations (Hedlund and Nonaka, 1993).

During the initial core team development at phase two and three of the NPD process, Tel-Co placed a lot of effort on developing similar mental models among the core team. A series of mental models was developed to facilitate ownership of the project by the core team. For example, a role-playing technique was used to create a feeling of ownership. Core members were asked to role play the owners of a start up firm. Also, to develop individual accountability among the team, individual mission statements were created and signed by all core team members. These mental models were referred to and reinforced throughout the development process. Tel-Co emphasized how the development and reinforcement of these mental models helped to steer the direction of the team and helped to facilitate communication (tacit knowledge transfer) among core team members.

In Soft-Co shared mental models were present among members of one core NPD team as a result of many previously shared work experiences. One project leader at Soft-Co stated that he often relied on several key people on his core team that could act without a lot of explicit directions from him. He described the need for less explicit communication among this core team because they were guided by similar mental models developed through many previous shared experiences that provided a similar base of understanding among them. The presence of these mental models appeared to facilitate the tacit knowledge transfer and transformation process among this core team.

Proposition 2b suggests that the tacit knowledge transfer and transformation process of a team is facilitated if the team members share similar mental models (shared understanding). Shared understanding can be acquired through shared work experiences or by developing and facilitating shared mental models or images among the team, as Tel-Co has done.

We explored the effectiveness of the tacit knowledge transfer and transformation process in relation to the degree of core team shared mental models within each company, figure 12 presents these findings below.

Figure 12: Proposition 2b - The Degree of Shared Mental Models within the Core Team and its Effect on the Team's Ability to Transfer and Transform Tacit Knowledge

Verifying Proposition 3: To verify hypothesis 3, we analyzed the degree of trust found among members of core teams, and between the core team and extended functional teams, and then analyzed this in conjunction with each team's ability to transfer and transform tacit knowledge.

Two types of trust were examined in this hypothesis. One type of team trust is called trust in team orientation and can be described as team members having reciprocal faith in others' intentions and behavior to work toward team goals rather than narrow, individual or functional goals or agendas (Madhavan and Grover, 1998). The other type of team trust is called trust in team members' technical competence and can be described as team members having reciprocal faith that other team members will complete the tasks in their area of expertise successfully either by involving themselves or other suitable persons (Madhavan and Grover, 1998).

What was expected from the research results from the three firms is a pattern similar to proposition 3. Proposition 3 states that the more trust (either type) there is among and between NPD teams the greater the effectiveness with which the tacit knowledge is transferred and transformed.

The case studies generally lend support for this proposition although it should be noted that this is case-based research and so these results should not be generalized to other companies engaged in NPD.

In general Comm-Co recognizes the significance of team trust as an enabling factor to transfer and transform tacit knowledge. Emphasis has been placed on building team trust in Comm-Co by conducting trust building activities between the core team and the extended functional teams. As well, the culture of Comm-Co promotes an understanding between design and development team members that trust is a critical component of NPD effectiveness, and one that needs to be continually facilitated.

However, with reference to the two types of trust given above, it was observed that more focus is placed on developing trust in team orientation than trust in technical competence at Comm-Co. A lack of trust in technical competence was observed between engineering and marketing functions. In several situations, engineering did not feel that marketing was competent in their development of customer requirements.

In general, Tel-Co recognizes the significance of team trust as an important element to effective communication and to the effective transfer and transformation of tacit knowledge. Much emphasis at Tel-Co is placed on conducting core team trust building activities. For example, social events and off-sight meetings were frequently used to help build the trust among core team members. Interview comments suggest that a lack of trust in technical competence was experienced between manufacturing, the core team and Q and A. These two areas of mistrust did cause communication difficulties (knowledge transfer) between these teams. This lack of trust however did improve when all NPD teams outlined their respective roles and responsibilities in the NPD process.

Soft-Co recognizes the significance of trust in technical competence as an important element in NPD effectiveness. High priority is placed on developing new product teams with individuals who have high levels of experience, technical competence and knowledge. As well, Soft-Co provides financial support and encouragement for the continued development of technical competence and skills.

Not as much emphasis however has been placed on trust in team orientation. Much less emphasis has been placed on building trust through trust building activities or social activities than what is found at Comm-Co and Tel-Co. There were communication difficulties observed as a result

of this lack of trust.

The results from this analysis suggest that the existence or lack of a type of trust will either enable or hinder the tacit knowledge transfer and transformation process. The case studies demonstrate that for both types of trust to exist they often have to be facilitated.

We explored the effectiveness of the tacit knowledge transfer and transformation process in relation to the degree of trust found within each NPD company and project, figure 13 presents these findings below.

Figure 13: Proposition 3 - The Degree of Trust among and between NPD Teams and the Effect on the Team's Ability to Transfer and Transform Tacit Knowledge

Chapter Six: Discussion of Themes, Significant Findings and Revised Framework

The goal of this research was to closely examine tacit knowledge, in particular the processes of tacit knowledge transfer and transformation with the hope of uncovering insights on how it may be better managed or leveraged in NPD.

In Chapter Five we provided qualitative findings from Soft-Co, Comm-Co, and Tel-Co pertaining to the examination of this subject matter in several areas. In this chapter we discuss the implications of common themes and significant findings pertaining to the analysis in Chapter Five.

This chapter is divided into three sections. Section one provides a discussion of the significant findings. In section two, the conceptual models formerly introduced in Chapter Three, a model of the Temporal Nature of Tacit Knowledge²⁶, and a model of Tacit Knowledge Transfer and Transformation in NPD²⁷ are reviewed and revised based on the significant findings. Section three highlights the implications of the revised models to the NPD process.

26

Recall that the Temporal Nature of Tacit Knowledge model focuses on the importance of tacit and explicit knowledge, and the importance of different tacit knowledge types (contextual and technical tacit) at different phases of NPD.

27

Recall that the Tacit Knowledge Transfer and Transformation model introduces and combines two concepts that provide an understanding of how effective transfer and transformation of tacit knowledge occur in the context of NPD, namely tacit knowledge externalization and amplification.

6.1 Discussion of Common Themes and Significant Findings

The following important themes and findings are discussed and their implications are reviewed:

1. The case studies indicate that there has been little recognition of and attention placed on managing tacit and explicit knowledge differences in NPD, for example:
 - NPD structure and processes did not recognize and support tacit knowledge use and transfer, and some explicit knowledge use and transfer
 - Communication mediums did not reflect or support tacit and sometimes explicit knowledge transfer
 - The presence of some team variables could be used to support and enable more effective tacit and explicit knowledge transfer
2. The case studies indicate that there is a lack of emphasis on contextual tacit knowledge transfer in NPD:
 - Marketing tacit knowledge is crucial to NPD
 - Product user tacit knowledge is crucial to NPD
3. The case studies indicate that NPD core team communication problems exist:
 - Difficulties externalizing tacit knowledge in cross functional core team composition
 - Difficulties amplifying tacit knowledge in homogenous core team composition
4. The case studies indicate that insufficient and/or poor documentation of tacit new product design or development knowledge has consequences:
 - Re-invention of the wheel for next generation products
 - Difficulty in after sales customer support due to lack of documentation
5. The case studies indicate that insufficient tacit knowledge transfer between teams collaborating on the same NPD project has consequences
 - Knowledge breakdowns²⁸ between NPD teams results in lost NPD time and lower quality development
 - Lower quality in after sales customer service

1. *Little Recognition of and Attention Placed on Managing Tacit and Explicit Knowledge Differences when Knowledge is Managed in NPD:*

Overall this research indicates little conscious attention has been placed on managing tacit and explicit knowledge differences when knowledge is managed in NPD. As a result of this lack of

support, knowledge breakdowns are occurring and also tacit and explicit knowledge is not being fully exploited or leveraged during each phase of development. Although both tacit and explicit knowledge is equally important to the development of a new product, our research found that explicit knowledge is the focus for many NPD teams. Virtually no conscious effort was placed on leveraging the tacit aspect of knowledge transfer in NPD, and there were also some examples of poor explicit knowledge management. This was not really surprising since the importance and management of tacit knowledge in business is still relatively new (Leonard and Sensiper, 1998; Nonaka and Konno, 1998). However, the number of consequences that this issue had on various facets of NPD was surprising to us.

In many of the cases, NPD structure and processes did not recognize and support tacit knowledge use and transfer, and explicit knowledge use and transfer. The research demonstrated that there was either too much structure, or a lack of structure at various phases which did not reflect, support and therefore leverage the predominant knowledge transfer type of that phase.

The knowledge management literature tells us that tacit and explicit knowledge transfer are leveraged (they become more effective) through different means. In general, support for tacit knowledge transfer requires an open environment that encourages people to observe, contextualize and share. Too much structure, process or standards may inhibit tacit knowledge sharing and transfer. Similarly, support for the effective transfer of explicit knowledge requires processes that support information gathering, categorizing and disseminating. A knowledge management structure that effectively leverages knowledge will outline where these two types of knowledge are used and transferred and what is needed to support their use and transfer.

Hence, Our findings confirm greater use of tacit knowledge transfer and transformation in the first three phases and greater use of explicit knowledge use and transfer in the end NPD phases. An effective knowledge management structure in NPD will support, enable and leverage this pattern of knowledge (type) use and transfer.

For example, at Tel-Co, there appeared to be too much structure to effectively support or enable tacit knowledge transfer and transformation (“too many issues had to be referred back to the Senior Portfolio Management team, these processes often impeded the innovation flow of the prototype design”) and too little structure for the effective transfer of explicit knowledge and effective implementation of explicitly defined project details (“processes are needed to ensure that the right product knowledge and an adequate level of product knowledge are transferred from the core team to the Life Cycle Team during the “product hand off” period so that after sales service does not suffer”). Consequences have occurred as a result of this inadequacy. The most important one being that knowledge is underutilized and therefore competitive advantage is not maximized. In the case studies, the product innovation flow (tacit knowledge transfer and transformation) was disrupted due to excess protocol in the initial phases, and product quality, delivery and after sales service suffered due to lack of support and attention on the transfer of important explicit product information and details between NPD functions.

Communication mediums used among the core team did not reflect or support tacit and explicit knowledge type transfer.

The qualitative analysis outlined many examples of some type of knowledge breakdown when team members were not co-located and/or did not communicate predominantly face to face during periods of high tacit knowledge transfer and transformation activities. For example frequent

situations of mis communication and misinterpretation were reported by Tel-Co when excessive e-mail exchange was used during the concept analysis and the product definition phases (phases that typically involve more tacit knowledge transfer and transformation). Interactions during which parties are not physically co-present, such as e-mail and telephone conversations, exclude meaningful and sensory information and contexts which are necessary for tacit knowledge transfer and transformation (Lave and Wenger, 1991; Nonaka 1990).

The presence of some team variables can also be used to support and achieve more effective tacit and explicit knowledge transfer. Our qualitative analysis outlined several common elements that help to achieve more effective tacit and explicit knowledge transfer among core team members, between the core team, and the extended functional teams in NPD, these are: building trust among the NPD core team members and with other functional members, creating NPD core team accountability and ownership of NPD tasks, and developing shared symbols and mental models among the NPD core team members. When knowledge is transferred, whether it is tacit or explicit knowledge, our findings show that the presence of these elements facilitates the effectiveness of the knowledge transfer process. Knowledge transfer (tacit and explicit) is received and retained more when these elements exist.

Trust is critical in a cross functional or inter-organizational team setting and withholding information due to a lack of trust can harm the process of knowledge articulation, internalization, and reflection (Hedlund and Nonaka, 1993). Our qualitative research examined the effects of two types of trust on the transfer and transformation of tacit knowledge between team members, trust in technical competence and trust in team members' orientation. Our research findings demonstrated that there appeared to be a correlation between a team's conscious effort to build

either kind of trust and the existence of that trust. For example, lack of trust in technical competence appeared to be somewhat common between various functional teams in NPD where no effort was made to clarify NPD roles and expectations between functions.

Creating team ownership and accountability, and the use of shared mental models and symbols were also reported as strong enablers to the creation, sharing, transfer and retention of knowledge.

2. *Lack of Emphasis on Contextual Tacit Knowledge: referring to the temporal nature of tacit knowledge model which outlines the relative emphasis on different tacit knowledge types at different phases, our research results observed a common lack of two types of contextual tacit knowledge in the development process that appear to be detrimental to product success, namely tacit knowledge transfer from marketing and the client in the first two to three phases of NPD.*

Interviewees from Soft-Co and Comm-Co cited examples that demonstrated a lack of client and marketing feedback and integration in the initial development phases. There appears to be a correlation between this lack of contextual tacit knowledge transferred in the initial phases and the failure of some products.

Tel-Co did not describe this as an issue, but they have a highly structured NPD process that incorporates feedback and integration from the client and marketing early in the development process. One of the primary objectives of their NPD process is frequent customer engagement and involvement. Hence their process recommends continual face to face contact with the lead customer at key phases of development (contextual tacit knowledge transfer). There are specific directives in this process to engage the lead customer as early as phase two and to use their input on the high-level customer requirements. Similarly, marketing appears to play a key role in the strategic review and assessment of the product concept at Tel-Co in the early phases of development. This aspect was regarded as an important part of the successful outcome of NPD

at Tel-Co.

3. *NPD Core Team Communication Problems: Many communication problems outlined in the qualitative analysis relate to difficulties with the tacit knowledge externalization and amplification process.*

Externalizing tacit knowledge is an important yet difficult part of effective knowledge transfer in NPD, NPD teams would benefit by understanding its role and the inherent difficulties with effectively achieving it. Similarly, tacit knowledge amplification within and among NPD teams is also an important yet difficult part of product design and development, NPD teams members, would benefit by understanding its role and the inherent difficulties with effectively achieving it.

Several engineers from Com-Co and two members of an NPD core team from Tel-Co (marketing and manufacturing) spoke of the difficulties and problems of sharing and transferring knowledge in a cross functional core team. Difficulties were especially described during phase two when the expanded new product definition was required from one cross functional core team.

Recall that tacit knowledge externalization has been described as the explication of tacit knowledge through its translation into comprehensible forms. The process of externalization is often difficult to achieve because tacit knowledge is personal and context specific and is stored in our mind's in the form of mental models (see Chapter Two for a description of externalization tools that can increase the success of externalizing tacit knowledge). As interviewees from Tel-Co and Comm-Co have pointed out, this process becomes especially difficult in a cross functional team where mental models can be quite different. One interviewee at Soft-Co pointed out that other barriers can also exist that can complicate this difficulty, such as too little time devoted to personal

contact (a rushed time to market environment), and physical distance between team members and team conflict. Our findings showed that face to face communication was more effective for successful tacit knowledge externalization, and that team trust was needed to provide a space where tacit knowledge can be externalized and received.

Although tacit knowledge externalization difficulties can exist among members of a cross functional core team, homogeneous core team composition also has its inherent drawback. One project manager of an NPD Team at Soft-Co described product failure as a result of NPD core team composition with little cross functional representation from marketing, the customer, sales and field support. Homogeneous teams are often subject to group think, a comfortable common view point leading to close mindedness and pressures toward uniformity (Janis, 1982), apparently “hearing a different perspective challenges the mind set of those in the majority sufficiently that they will search beyond what initially appears to be an obvious solution” (Leonard and Sensiper, 1998).

4. *Insufficient and/or Poor Documentation of Tacit New Product Design or Development Knowledge has Consequences.*

All three firms commented on a lack of new product documentation or poor documentation standards that made sharing or interpreting existing code difficult and often resulted in difficulties with after sales customer support for new products, or the need to reinvent product solutions during next generation development because of the unavailability of adequate new product documentation.

5. *Insufficient Tacit Knowledge Transfer between Teams Collaborating on the Same NPD Project has Consequences*

Tel-Co and Comm-Co described knowledge breakdowns between teams collaborating on the

same NPD project when explicit knowledge transfer was the sole source of knowledge transfer between these teams (which also resulted in loss of NPD time because of mistakes that had to be rectified). Tel-Co described difficulties in poor quality after sales customer service when the new product hand off phase was completed by the core team to the Life Cycle team through a “throw it over the wall” knowledge transfer process involving little transfer of important tacit new product design and development knowledge still embedded in the mind’s of the NPD core team. Product know-how and intuition are important tacit aspects of new product knowledge that needs to flow between members collaborating on the same team. Given the importance of the intuitive aspect of new product knowledge, this highlights the need for a strategy that effectively transfers tacit NPD knowledge between teams collaborating on the same NPD project.

6.2 - Revised Framework

Some of the common and significant findings presented above have been used to validate and expand the temporal nature of tacit knowledge model and the tacit knowledge transfer and transformation model.

Both revised models provide prescription on how tacit knowledge can be leveraged further to achieve better NPD outcomes. These prescriptive models are provided next followed by an outline of the practical application of each model in NPD.

6.2.1 Revised Model 1: The Temporal Nature of Tacit Knowledge

The Temporal nature of tacit knowledge model described our proposition on the relative

importance of different tacit knowledge types at different phases in NPD (proposition 1b²⁹). Our case study findings validated the model at all phases except the initial NPD phases where our results confirmed the use of more technical over contextual tacit knowledge (Soft-Co and Comm-Co did not fit our proposition, they used more technical tacit knowledge than contextual tacit knowledge in the initial NPD phases).

To understand the deeper implications of the temporal model we examined other qualitative findings that pertain to the relative emphasis on different tacit knowledge types at NPD phases. A correlation between product failure and the lack of tacit knowledge transfer from the client and marketing (contextual tacit knowledge transfer) in the initial NPD phases were described by some interviewees from all companies. No other patterns pertaining to the importance of different tacit knowledge types at other phases was discovered.

Based on our findings, we revised the temporal nature of tacit knowledge model to prescribe the transfer/integration of tacit knowledge from the customer and marketing in the initial NPD phases in order to potentially achieve greater product success. In some of the NPD cases, the transfer of contextual tacit knowledge was more important than the transfer of technical tacit knowledge to investigate the viability of the product concept.

Many other types of tacit knowledge comprise our definition of contextual tacit knowledge, a more in-depth analysis of the correlation between product success and the importance, transfer

29

When the model was first introduced under hypothesis 1b, we speculated that contextual tacit knowledge would exist predominantly in the beginning and end phases of NPD and that technical tacit knowledge would exist predominantly in the mid phases of NPD. Our research results did not confirm or refute this speculation. Tel-Co seemed to fit the pattern of contextual and technical tacit knowledge use outlined by the temporal model, Comm-Co and Soft-Co did not fit this pattern.

and integration of other contextual tacit knowledge types at different phases would need to be conducted across a greater sample size for the full value of the temporal model to be realized. But for now we introduce the temporal model as a conceptual tool for understanding the relative importance of integrating different tacit knowledge types at different NPD phases, and by extension, how NPD core teams should be constructed at each phase and the influence that this might have on the outcome of the new product. The revised temporal model is provided below followed by a brief description of tacit knowledge transfer and integration from the client and marketing in the initial NPD phases.

Figure 14: The Temporal Nature of Tacit Knowledge Requirement & Team Composition

Tacit Knowledge Transfer From the Client in the initial Phases of NPD

Our research suggests that tacit knowledge transfer from the client is required during the initial development phases, in particular, to improve NPD success.

Concept justification should account for individual experiences and expressions. Justifying the product concept during the first two phases of NPD should be more of a qualitative exercise than a quantitative exercise involving the transfer of tacit knowledge from the client, "concept justification should be expanded to include criteria that account for individual experiences and expressions. A concept is an expression of shared tacit input, but it is not identical with tacit knowledge. Additional meaning will be given to the concept as the justification phase proceeds. All the participants in this process will bring their own views, their own thoughts, and emotions to the table, and the meaning of the concept itself will change through this group process" (Von Krogh, Ichijo and Nonaka, 2000, p. 88).

Focus groups with the lead customer to observe interactions with the product. When a product concept is first created, it can be reviewed by leading consumers. They suggest that one way of doing this is to conduct focus groups with the lead consumers and observe consumer interactions with the product, "at the prototyping phase, prototypes can be shown to customers to get their preliminary reaction on the design. The customer can be given some degree of freedom in operating the prototype while the designers watch his or her interaction" (Von Krogh, Ichijo and Nonaka, 2000).

Service technicians are also natural participants during prototype creation, since their input will enhance the serviceability of the end product.

Tacit Knowledge Transfer From Marketing during the Initial NPD Phases

Our research suggests that tacit knowledge transfer from marketing is required during the initial development phases, in particular, to improve NPD success. Other research findings (Song, Thieme and Xie, 1998) suggest that new product success seems to be more probable when joint involvement exists between marketing and R & D in the market opportunity and analysis phase and when marketing takes on the role of the focal function³⁰ of this joint involvement during these phases. They suggest that joint involvement between marketing and R& D in this phase is critical because it facilitates market uncertainty reduction, which increases the likelihood of developing a new product with high demand and competitive advantage.

6.2.2 Revised Model 2: Tacit Knowledge Transfer and Transformation in NPD

NPD is seldom the undertaking of one individual. It typically requires processes of tacit knowledge transfer and transformation within teams for new products to be developed. The purpose of the tacit knowledge transfer and transformation model introduced in Chapter Three was to outline elements that describe how this transfer and transformation process can be more effectively achieved. Our conceptual model argued that the effectiveness depends on tacit knowledge externalization and amplification. Understanding how to enable these two processes helps us to potentially achieve a better NPD result. Up to now our research has focused on how to enable these two processes.

From Chapter Five and Six, our findings have shown that the process of tacit knowledge transfer and transformation is important to NPD, but that there are other tacit knowledge related

30

Focal function is described as the function that has greater relative importance during the joint NPD activities of each phase.

processes that are also equally critical to NPD success. We have incorporated these into our revised framework, which we now call *Leveraging/Exploiting Tacit Knowledge in NPD*. A title that is intended to imply harnessing tacit knowledge to achieve better NPD outcomes. A broad description of the model is provided below.

Figure 15: Leveraging/Exploiting Tacit Knowledge in NPD

Overall our research told us that there was little recognition of and attention placed on managing tacit and explicit knowledge differences when knowledge is managed in NPD. Ultimately knowledge management strategies should help to leverage both the tacit and explicit knowledge. Our thesis is limited to exploration on tacit knowledge in NPD so we have limited our recommendations to strategies for leveraging tacit knowledge.

To leverage tacit knowledge in NPD, this model suggests that three critical tacit knowledge related processes be supported and facilitated, these are: the transfer and transformation of tacit knowledge, the codification (documentation) of tacit new product design and development knowledge, the transfer of tacit knowledge between NPD teams. Our model presents each one of these processes above as a strategy to imply that there are a number of different methods and/or processes which support and enable these processes in the context of NPD.

You will notice that each tacit knowledge related strategy is directed at specific phases of the NPD process. The findings from our qualitative analysis suggest that various tacit knowledge issues (deficiencies) occur more in some phases than others (typically tied to the objectives of the NPD phase).

Hence, to leverage tacit knowledge and achieve the greatest value added to NPD outcomes the model recommends support for processes of tacit knowledge transfer and transformation more so in the beginning phases of NPD, where we would find the greatest use of this process as the concept transforms from a tacit concept to the first documented design of the product; support for codifying and documenting tacit knowledge, this would be more appropriately directed toward the mid phases of NPD where design and development decisions are being made and finalized

(codifying tacit knowledge should include recording beliefs and assumptions along with design decisional steps); support for the transfer of knowledge between teams, specifically tacit knowledge transfer between NPD teams (collaborating on the same NPD project) is what is required to improve quality of manufacturing, delivery and after sales customer service.

Hence facilitating the tacit knowledge transfer and transformation process of the first three phases may improve upon product innovation; codifying and documenting tacit new product knowledge may reduce problems of having to reinvent the wheel, and may facilitate next generation product development; and knowledge transfer strategies between NPD teams that employ methods to transfer the tacit component of new product knowledge, especially between the core NPD team and the product life cycle team may help to improve the quality of after sales customer service for new products.

Next we revisit/summarize (many of these strategies have already been discussed throughout the thesis) strategies for effectively achieving these critical tacit knowledge processes.

Strategy for the Transfer and Transformation of Tacit Knowledge in NPD

Some of the elements that support and facilitate the processes of tacit transfer and transformation are: understanding how to effectively externalize tacit knowledge (see externalization tools, refer to page 17), understanding the tacit knowledge amplification process and how to manage it (refer to pages 19 - 22), understanding the importance of face to face communication to enable tacit knowledge transfer and transformation (refer to pages 105 - 106), understanding the advantages/disadvantages of core team heterogeneity and homogeneity on the tacit knowledge transfer and transformation process (refer to pages 122 - 125), understanding the

advantages of shared mental models and team trust to facilitate the tacit knowledge transfer and transformation process within teams (refer to pages 126-128). See results of qualitative exploration into factors that enable the tacit knowledge transfer and transformation process, such as, using the core team approach to develop new products, co-locating core team members, ensuring that the core team members remain the same throughout the NPD cycle, creating formalized NPD structure and process to facilitate knowledge linkages and knowledge transfer, creating ownership of NPD tasks, creating small teams--the core team and other functional teams in NPD, using project and team incentives, and ensuring that the project leader for the NPD initiative is optimistic and positive (refer to pages 117 - 122).

One element that we have not discussed but which is important to effective tacit knowledge transfer and transformation, especially during the first two phases of NPD, is time. A lack of it can dramatically hinder this process. The transfer of tacit knowledge is likely to take substantial time and energy and involves a good blend of reflection about group work (Von Krogh, Ichijo, Nonaka, 2000), managers therefore need to be aware of the substantial time component that is involved when this process is being managed. Unfortunately, many business strategies often do not account for the time it takes to express new ideas in a form that others can understand.

Strategy for Codifying (Documenting) Tacit Knowledge in NPD

Some of the elements that support and facilitate the processes of codifying and documenting tacit NPD knowledge: developing standards for documenting; recording beliefs, assumptions along with design decisional steps; facilitating the capture of design experiences; instituting methods to retain context along with information stored; creating a well-indexed knowledge of similar design problems faced in earlier groups and teams; live documentation/collaborative tools are also

suggested.

Strategy for the Transfer of Tacit Knowledge Between NPD Teams

An important part of new product information and knowledge is highly contextual carrying intuitive and actionable knowledge that cannot be communicated solely through explicit knowledge transfer. Situations should be avoided where documents are “thrown over the wall.” Given the above we suggest that firms take additional measures to transfer the tacit component of product knowledge between NPD teams collaborating on the same NPD project.

Some of the elements that support the transfer of tacit based new product knowledge between NPD teams: assigning a spoke person to each important explicit (document) to help teams and recipients of explicit knowledge make full sense of NPD documents; providing training for facilitators and interpreters of knowledge, this person should not only be fluent in technical details, they should also be trained as helpers, facilitators and interpreters of knowledge for others, “spokes people need to be able to take a generalist’s view of operations as well as that of the technical expert. They should have pedagogical skills and see every conversation as an opportunity to increase the receiving unit’s capacity to act rather than an irritating distraction in their own day. Training spokes people is another key lever for reducing costs of knowledge exchange.” (Von Krogh, Ichijo and Nonaka, 2000).

6.3 Knowledge Management Implications

Tacit knowledge is important to the development of new products yet it is often underutilized. If companies are to consistently and repeatedly exploit and leverage knowledge to the fullest to achieve competitive advantage then knowledge management systems must be developed to

ensure that critical NPD (explicit and tacit) knowledge related processes are supported.

We introduce in this chapter two models that provide both insight and understanding into what tacit knowledge processes are critical to NPD outcomes. *The Temporal Nature of Tacit Knowledge* model is focused on the input of various types of tacit knowledge at various phases of NPD. The full value of this model will be achieved when future empirical research discerns the relative importance of different tacit knowledge types along the NPD cycle to achieve greater product success.

The second model, *Leveraging Tacit Knowledge in NPD*, is focused on the types of knowledge strategies that are required to leverage and support critical tacit knowledge processes throughout the NPD cycle. This model suggests that three tacit knowledge related processes be supported and facilitated along the NPD cycle, these are: the transfer and transformation of tacit knowledge, the codification (documentation) of tacit new product design and development knowledge, the transfer of tacit knowledge between NPD teams collaborating on the same NPD project.

Chapter Seven: Implications and Limitations of this Research & Suggestions for Future Research

7.1 Implications of the Research

7.1.1 Practical Implications

Our findings have several implications for new product developers:

Firstly, train NPD managers and team members on aspects of managing explicit and tacit knowledge in NPD—refer to the Temporal Nature of Tacit Knowledge Model and the Model for Leveraging/Exploiting Tacit Knowledge in NPD to provide understanding on the critical tacit knowledge processes that are to be supported to achieve better NPD outcomes. When managers and team members are sensitized to the importance and value of the knowledge management perspective of NPD, managers and team members will find ways to apply it fruitfully (Madhavan and Grover, 1998).

Develop methods that foster the building of trust in technical competence and trust in team members' orientation in NPD teams. Our research showed us that team building exercises and social events were helpful for building trust in team orientation. Performance feedback is effective in building trust in technical competence between team members (Madhavan and Grover, 1998). Building maps of expectation between functional teams may help to build trust in technical competence between functional teams in NPD (Von Krogh, Ichijo and Nonaka, 2000).

Screen NPD team members for the extent of their shared mental models. Our research showed that shared mental models facilitate the externalization and amplification of tacit knowledge.

Train NPD members to externalize and amplify tacit knowledge well. Managers can train individuals to communicate some of the tacit dimensions of their knowledge - through prototyping, drawing, demonstrating, expressing ideas through metaphors, analogies and storytelling. Managers can also train/inform NPD members on key aspects of effectively managing the knowledge building process within teams.

Ensure that NPD core team members remain the same throughout the NPD cycle, and where more than two teams exist, ensure that one team members transitions from one team to the next to maintain knowledge continuity from one phase to the next.

Build NPD teams based on the importance of transferring and integrating tacit knowledge at NPD phases.

7.1.2 Academic Implications

This research compliments prior research that outlines the importance of managing tacit knowledge in NPD (Leonard and Sensiper, 1998; Madhavan and Grover, 1998; Nonaka and Konno, 1998; Ramesh and Tiwana, 1999).

First of all we know that much empirical research needs to be conducted in the area of tacit knowledge management. The concept of tacit knowledge is complex, moreover systems that manage and enable it are equally complex. Empirical research is needed to establish theory and advance the academic perspective on knowledge management in NPD.

For academics conducting research on efficiency in NPD, more focus should be placed on seamless knowledge transfer (often achieved by reinforcing tacit knowledge transfer between NPD teams and phases) between NPD teams as a variable of efficiency through NPD phases. Our findings suggest that much time and resources in NPD are spent repairing the damage of knowledge breakdowns within and between teams because of this discontinuity of knowledge.

For academics conducting research on NPD success factors, our findings suggest that the input of various tacit knowledge types at distinct phases may play a significant role in new product success. Tacit knowledge transfer could potentially play an important variable in future empirical research on NPD success factors.

For academics conducting consumer research, methods that maintain intuitive tacit forms of feedback from consumers are important and would benefit by being researched further.

7.2 Limitations of the Research

This study has the inherent limitations that come with qualitative research. Qualitative findings which report in-depth descriptions and interactions between complex variables such as this study, are often difficult to replicate, transfer and generalize to other environments. Moreover, the small sample size of three companies also leaves the generalizability of these findings in question. The research concludes with two models. In particular these models will also need to be tested with a larger sample to be valid within settings and across settings.

Although measures were taken to reduce errors of judgement and biases (these measures have been outlined in the methodology), it is probable that some biases exist in the interpretation

and the discussion of the findings.

This research was exploratory research. Because of the complex and uncertain nature of the research topic, the interview questions were developed to be clear and simple. Although this facilitated the interview process, there is also concern that some of the questions may not have adequately captured the complexity of the subject matter.

The objective of this research was to explore the transfer and transformation of tacit knowledge in NPD. Limitations due to the availability of new product personnel at all companies have left gaps with respect gathering data about this subject matter at various phases of NPD development. In particular, the transfer of knowledge between development and manufacturing was not well established because only one interviewee working in manufacturing was available for an interview.

This subject matter also looked at a limited number of variables pertaining to team composition and its correlation to the effective transfer and transformation of tacit knowledge. In reality many more variables affect and enable the tacit knowledge transfer and transformation process in NPD.

7.3 Suggestions for Future research

This research has raised several additional questions that should be addressed in future research.

The benefits of employee co-location and frequent face to face interaction were discussed by this research and other researchers (Nonaka, 1990; Nonaka and Konno, 1998). The co-location

factor is considered critical to the effective transfer and transformation of tacit knowledge because much of the knowledge that is shared and exchanged in NPD is highly contextual and intuitive and therefore best transferred through face to face mediums. Thus, the argument for co-locating members of NPD teams is very strong and credible. At the same time economic forces and other issues make face to face interaction in some new product development settings less realizable. Future research should therefore investigate the effectiveness of settings that replicate face to face interaction on the tacit knowledge transfer and transformation process, such as full motion interactive video, interactive on line collaborative work spaces and peripheral awareness tools for context gathering and sense-making.

The research introduces two prescriptive models as a part of the concluding framework. These models essentially provide a better understanding of how tacit knowledge can be leveraged and facilitated in an NPD environment. Future research will need to test these two models in similar and dissimilar settings so that the models can be validated and expanded further.

This subject matter also looked at a limited number of variables that affect the transfer and the transformation of tacit knowledge in NPD. In reality many more variables affect the transfer and the transformation of tacit knowledge, such as administrative systems, policies, organizational culture, top management support and strategic vision to name a few. Understanding how these variables can affect the transfer and the transformation of tacit knowledge will make interesting and useful avenues for future research.

Psychology literature provides scales for measuring tacit knowledge at the individual level (Wagner 1985). Organizations would also benefit by understanding the level of knowledge creation

required in their organizations. Scales for measuring knowledge creation will provide insight into the value and input of intellectual capital type for each organization.

7.4 Conclusion

Knowledge management is a relatively new discipline to the world of NPD. Based on the results of this research and other research (Ramesh and Tiwana, 1999) it would seem that very few firms developing new products have developed knowledge management systems to ensure that critical knowledge processes are supported and to ensure the ongoing exploitation of tacit and explicit knowledge in general to contribute to competitive advantage. Support for the management of tacit knowledge in NPD is needed to improve upon innovation, efficiency, quality development, manufacturing, and after sales customer service, needed in today's competitive environment.

In this research our main argument has been that NPD firms should establish a knowledge management system to help repeatedly leverage tacit knowledge (intellectual capital) in NPD and facilitate knowledge creation, transfer and reuse. After in-depth qualitative research into the transfer and transformation of tacit knowledge in NPD, this thesis concludes with a framework to help support this objective.

Our understanding of tacit knowledge in NPD is nascent. This research presents a path toward that understanding, and it will also serve to instigate more discussion. More research is necessary if we are to reveal the mysteries of tacit knowledge and use it fully to our advantage to achieve greater NPD success.

References

- Amidon Rogers, D. M. (1996)., "The Challenge of Fifth Generation R & D," *Research Technology Management*, July-August
- Argot, L. (1989)., "Agreement about Norms and Work Unit Effectiveness: Evidence from the Field," *Basic and Applied Social Psychology*, 10, 131-140
- Badaracco, J.L., (1991)., *The Knowledge Link: How Firms Compete Through Strategic Alliances*. Boston, MA: Harvard Business School Press
- Block, N. (1990)., "The Computer Model of Mind," *Thinking: An Invitation to Cognitive Science*, Vol. 3
- Bruner, J.S. (1973). *Beyond the Information Given*. J.M. Anglin, ed.
- Burrell, G. and Morgan, G. (1979)., *Sociological Paradigms and Organizational Analysis*. London: Heinemann.
- Campbell, D. (1960)., "Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes," *Psychological Review*, 67(1960), 380-400
- Clark, K.B. and T. Fujimoto, (1991)., *Product Development Performance: Strategy, Organization and Management in the World Auto Industry*. Cambridge: Harvard Business School Press.
- Clark, K.B. and S.C. Wheelright, (1992)., "Organizing and Leading "Heavyweight" Development Teams," *California Management Review*, 34 (3), 9 -28
- Clemmons Rumizen, M. (2002), *The Complete Idiot's Guide to Knowledge Management*. John A. Woods, CWL Publishing Enterprises.
- Cooper, R. G. (1993)., *Winning at New Products: Accelerating the Process from Idea Generation to Product Launch*. Addison - Wesley Publishing Company.
- Cooper, R.G., and Kleinschmidt, E.J. (1986)., "An Investigation into the New Product Process: Steps, Deficiencies and Impact," *Journal of Product Innovation Management*, 3:71-85
- Cooper R.D. and Schindler, P.S. (1989)., *Business Research Methods*. McGraw Hill.
- Court, A.W. (1997)., "The Relationship Between Information and Personal Knowledge in New Product Development," *International Journal of Information Management*, 17(2)
- Daft, R.L. and Weick, K.E. (1984)., "Toward a Model of Organizations as Interpretive Systems," *Academy of Management Review*, 9(2), 284-295
- Davenport, T. and Prusak, L. (1998)., *Working Knowledge: How Organizations Manage what they*

Know. Harvard Business School Press

- Dougherty, D. and T. Heller (1994)., "The Illegitimacy of Successful Product Innovation in Established Firms," *Organization Science*, 5, 200-218
- Drucker, P. (1991)., "The New Productivity Challenge," *The Harvard Business Review*, Vol. 69, November-December, p. 53-66
- Drucker, P. (1993)., *The Post Capitalist Society*. Harper Business Press.
- Eder, W.E. (1998) *Information Systems for designers*, in: Proceedings of the Proc. International Conference in Engineering Design, Harrowgate, pp. 1307-1319
- Finholt, T.A. (In press). "Outsiders on the Inside: Sharing Know-how through Computer Message Archives," *Management Information Systems Quarterly*
- Griffin, Abbie and Hauser R. (1996)., "Integrating R&D and Marketing: A Review and Analysis of the literature," *Journal of Product Innovation Management*, 13:191-215
- Gupta, Ashok, Raj, S.P., and Wilemon, D. (1986)., "A Model for Studying R&D Marketing Interface in the Product Innovation Process," *Journal of Marketing*, 50:7-17
- Hansen, M, N. Nohria and Tierney, T. (1999)., "What's Your Strategy for Managing Knowledge," *Harvard Business Review*, March-April
- Haines, G. H. Jr. (1978). "Comments on Three Papers on The Effect of Information on Market Behavior," *American Marketing Association, Proceeding Series*
- Heath, S.B. (1984)., " Linguistics and Education," *Annual Review of Anthropology*, 13, 251-274
- Hedlund, G. (1994)., "A Model of Knowledge Management and the N-form Corporation," *Strategic Management Journal*, Vol. 15, 73-90
- Hedlund, G. and Nonaka, I. (1993)., "Models of Knowledge Management in the West and Japan," in *Implementing Strategic Processes: Change Learning and Cooperation*, 117-144
- Hise, R.T., O'Neal, L., Parasuraman, A., and McNeal, J. (1990)., "Marketing/R&D Interaction in New Product Development: Implications for New Product Success Rates," *Journal of Product Innovation Management*, 7:142-155
- Holland, T. (1985)., "Integrating Research and Practice in Social Work Education," *Journal of Applied Social Sciences*, 9(2), 165-176
- Hutchins, E. and Klausen, T. (1996)., "Distributed Cognition in an Airline Cockpit," *Cognition and Communication at Work*, Yrjo Engstrom and David Middleton, eds. Cambridge, UK: Cambridge, 15-34

- Iansiti, M. and MacCormack, A. (1997)., "Developing Products on Internet Time," *Harvard Business Review*, September-October
- Imre, R.W. (1985)., "Tacit knowledge in Social Work Research and Practice," *Smith College Studies in Social Work*, 55(2), 137 - 149
- Janis, I.L. (1982). *Groupthink*. Boston, MA: Houghton Mifflin
- Knapp, E. (1998)., "Knowledge Management," *Business and Economic Review*, July-Sept, p. 3-6
- Kreitner, R. and Konicki, A. (1992)., *Organizational Behavior*. Homewood, IL: Richard D. Irwin
- Kogut, B. and Zander, U. (1992)., "Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology," *Organizational Science*, 3(3), 383-97
- Lave, J. and E. Wenger. (1991)., *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.
- Leonard, D. and Sensiper, S. (1998), " The Role of Tacit Knowledge in Group Innovation," *California Management Review*, Vol. 40, No. 3, Spring
- Leonard-Barton, D. (1995)., *Wellsprings of Knowledge*. Boston MA: Harvard Business School Press
- Levine, J.M. and Moreland, R.L., (1991). Culture and Socialization in Work Groups. In L.B. Resnick, J. M. Levine, and S.D. Teasley (Eds.), *Perspectives on Socially Shared Cognition* (p. 257-279). Washington, DC: American Psychological Association.
- Madhavan, R. and Grover, R. (1998)., "From Embedded Knowledge to Embodied Knowledge: New Product Development as Knowledge Management," *Journal of Marketing*, Vol. 62, October, 1-12
- Maturana, H. and Varela, F. (1987). *The Tree of Knowledge*. Boston. MA, New Science Library
- Marshall, C. and Rossman, G.B. (1989)., *Designing Qualitative Research*. Sage Publications Inc.,
- Moenaert, R.K. and DeMeyer, A. and Souder, W.E. and Deschoolmeester, D. (1995)., "R&D/Marketing Communication during the Fuzzy Front End," *IEEE Transactions on Engineering Management*
- Moorman, C., R. Deshpande, and Zaltman, G. (1993)., "Factors Affecting Trust in Market Research Relationships," *Journal of Marketing*, 57, 81-101
- Nelson, R. R. and Winter S. G. (1982)., *An Evolutionary Theory of Economic Change*. Cambridge, MA: Belknap
- Nonaka, I. (1991)., "The Knowledge Creating," *Harvard Business Review*, November-December

- Nonaka, I. and Takeuchi, H. (1995)., *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation*. Oxford University, Press
- Nonaka, I. and Konno, N. (1998)., "The Concept of "Ba": Building a Foundation for Knowledge Creation," *California Management Review*, Spring, 40(3), 40-54
- Numata, J. and Taura, T. (1996)., "A Case Study: A Network System for Knowledge Amplification in the Product Development System," *IEEE Transactions on Engineering Management*, Vol. 43, No. 4, November
- Olson, E.M., and Walker and Orville, C.Jr. and Ruekert, R.W. (1995)., "Organizing for Effective New Product Development: The Moderating Role of Product Innovativeness", *Journal of Marketing Research*, 59:31-45
- Patel, V.L., D.R. Kaufman, and Arocha, J.F. (1995)., "Steering Through the Murky Waters of Scientific Conflict: Situated and Symbolic Models of Clinical Cognition," *Artificial Intelligence in Medicine*, 7(5), 413-438
- Patton, M. (1990)., *Qualitative Evaluation and Research Methods*. 2nd edition Sage, Thousand Oaks
- Pelled, L.H. (1996), "Demographic Diversity, Conflict, and Work Group Outcomes: An Intervening Process Theory," *Organizational Science*, 7/6, 615 - 631
- Phillips, J.W. (1981), "Assessing Measurement Error in Key Informant Reports: A Methodological Note on Organizational Analysis in Marketing," *Journal of Marketing Research*, 18, P 395-415
- Polanyi, M. (1962)., *Personal Knowledge: Towards a Post Critical Philosophy*. Harper Torch Books
- Polanyi, M. (1966)., *The Tacit Dimension*. Gloucester, MA.
- Pyzdek, T. (1991)., *What Every Manager Should Know About Quality*, New york: Marcel Dekker
- Quinn, J.B, Anderson, P., and Finkelstein, S. (1996). "Managing Professional Intellect: Making the Most of the Best," *Harvard Business Review*, March - April
- Ramesh, B. and Tiwana, A. (1999), "Supporting Collaborative Process Knowledge Management in New Product Development Teams," *Decision Support Systems*, 27, p 213-235.
- Reber, A.S. (1989), "Implicit Learning and Tacit Knowledge", *Journal of Experimental Psychology*, 118(3), 219-235
- Romer, P. (1995)., "Beyond the Knowledge Worker," *World Link*, January-February, p. 56-60
- Ruggles, R., (1998)., "The State of the Notion: Knowledge Management in Practice," *California Management Review*, 40 (3)

- Saint-Onge, H. (1996)., "Tacit Knowledge: The Key to the Strategic Alignment of Intellectual Capital," *Journal of Strategy and Leadership*, March/April 1996
- Serve, I. S. (1990)., *New Product Development and Marketing*. Praeger Publishers
- Simon, H.A. (1985)., "What we Know about the Creative Process," *Frontiers in Innovative and Creative Management*, Robert L. Kuhn, ed., 3 - 20
- Song, X.M. and Parry, M. E. (1993)., "R&D Marketing Interface in Japanese High-technology Firms: Hypotheses and Empirical Evidence," *Journal of Academy of Marketing Science*, 21:125-133
- Song, X.M., Thieme, R.J and Xie, J. (1998)., "The Impact of Cross-functional Joint Involvement across Product Development Stages: An Exploratory Study," *Journal of Innovation Management*, 15: 289 - 303
- Spender, J.C., (1996)., "Competitive Advantage from Tacit Knowledge? Unpacking the Concept and its Strategic Implications," in Bertrand Mosingeon and Amy Edmonson, eds., *Organizational Learning and Competitive Advantage* (London: Sage Publications), p. 56-73
- Stainer and Nixon. (1997). *Managing Product Innovation*. Praeger Publishers
- Stata, R. (1989)., "Organizational Learning - The Key to Management Innovation," *Sloan Management Review*, 17 (Spring): 63-74
- Strauss A. (1987)., *Qualitative Analysis for Social Scientists*. Cambridge University Press, Cambridge
- Sutton, R. I. and Hargadon, A. (1996)., "Brainstorming Groups in Context: Effectiveness in a Product Design Firm," *Administrative Science Quarterly*, 41 (4), December
- Teece, D., (1998)., "Research Directions for Knowledge Management," *California Management Review* 40 (3)
- The American Productivity and Quality Center. (2000). "Building and Sustaining Communities of Practice: Continuing Success in Knowledge Management," American Productivity and Quality Center. (Online). URL:<http://www.apqc.orgproposal/6576km6/>.
- Tiwana, A. (2002). *The Knowledge Management Tool Kit*, Prentice Hall
- Van Maanen, J., Dabbs, J. and Falkner, R. (1982)., *Varieties of Qualitative Research*. Sage, Beverly Hills
- Veryzer, Jr., R.W. (1998)., "Discontinuous Innovation and the New Product Development Process", *Journal of Innovation Management*, 15: 304-321
- Von Krogh, G. (1998), "Care in knowledge Creation," *California Management Review*, Vol. 40, No.3, Spring

- Von Krogh, G., Ichijo, K. and I. Nonaka, (2000)., *Enabling Knowledge Creation*. Oxford University Press Inc.
- Von Krogh, G. and J. Roos (1996)., *Knowledge Management: Perspectives on Cooperation and Competition*. London-Sage
- Wagner, R.K. (1987)., "Tacit Knowledge in Every day Intelligent Behavior," *Journal of Personality and Social Psychology*, 52(6), 1236-1247
- Walsh, J.P. and Ungson, G.R. (1991)., "Organizational Memory," *Academy of Management Review*, 16 (1), 57-91
- Weick, K.E., (1979)., *The Social Psychology of Organizing*. Addison - Wesley, Reading
- Wenger, E. (1998)., *Communities of Practice: Learning, Meaning and Identity*. Cambridge: Cambridge University Press
- Wheelwright, S.C. and Clark, Kim B. (1992). *Revolutionizing Product Development*. New York: The Free Press
- Wind, Y and Mahajan, V. (1988). " New Product Development Process: A Perspective for Reexamination," *Journal of Product Innovation Management*, 66: 304 - 310
- Yin, R. (1989)., *Case Study Research: Design and Methods*. Newbury Park, CA Sage Publications
- Yin, R. (1994)., *Case Study Research*. 2nd Edition, Sage, Thousand Oaks
- Zack, M.H. (1999)., "Managing Codified knowledge," *Sloan Management Review*, Summer 1999
- Zand, D.E. (1972)., "Trust and Managerial Problem Solving," *Administrative Science Quarterly*, 17(2), 229- 239
- Zand, D.E. (1981)., *Information, Organization, and Power: Effective Management in Knowledge Society*. New York: McGraw Hill

Appendix A - 1**Consent Form****Research Topic: The Transfer and Transformation of Tacit Knowledge in New Product Development**

Contact Information: For further information on this project please contact,

Researcher: Julia Fulton, (613) 299 - 4111, Email: fultoj@magma.ca

Education Institution: Carleton University – Eric Sprott School of Business

Thesis Supervisor: Dr. Siva Pal, 520 - 2600, ext. 2390, Email: siva_pal@carleton.ca

If you have any concerns about any aspect of this study, you may contact

the Department Chair: Dr. Vinod Kumar, 520 - 2600, ext. 2379, Email: vinod_kumar@carleton.ca

Purpose of the Consent Form:

The purpose of this document is to ensure that interview participants receive sufficient information about their rights as interview subjects and to explain the purpose of the research they are contributing to. The interview subject will retain a copy of the consent form as will the researcher.

Statement of Research to be Undertaken:

The undersigned is being invited to participate in the research process for a Master's of Business Administration thesis titled "The Transfer and Transformation of Tacit Knowledge in New Product Development". This research examines how the tacit knowledge of NPD employees is transferred, transformed and integrated into the development of a new technological product. It proposes that the effective transfer and integration of tacit knowledge into a new technological product occurs through continuous processes of tacit knowledge externalization and then tacit knowledge amplification at each phase in NPD. This research examines these transfer and transformation processes, the conditions that encourage the transfer and transformation of tacit knowledge and the associated difficulties of these processes. The research will be conducted as a case study in three technology firms. The results from this comparative research will be incorporated into a framework, which will describe in part how tacit knowledge may be leveraged in new product development.

Interview Subjects: Because this research analyzes the operation of tacit knowledge through out new product development, NPD employees will be interviewed from a variety of disciplines involved in the development of a new product: marketing, engineering, testing and verification, manufacturing and planning. Ten employees will be interviewed within each firm.

Potential Risks:

There are no social, financial or other risks associated with the interview process. However some of the questions I would like to ask may be related to sensitive issues within your company, for example questions about your company's culture and your company's attitudes towards their employees in NPD. These may affect the sharing of knowledge and are important to this research. It is important that interview participants be aware that this research will ensure strict anonymity and confidentiality of their responses. Interviewee responses will not be given to senior members of their firm, names will not be mentioned in the final thesis or other documents and publications that might stem from this research.

Interviewees Rights:

The interviews at (company) will be conducted on a voluntary basis. It is the interviewees right to stop the interview at any time and to decline response to any questions throughout the interview process.

Process for Ensuring Anonymity:

- With the permission from the interview subject, the interview will be recorded.
- To ensure high standards of anonymity for each interview subject, a coding scheme will be used to identify each interview subject. All transcribed documents from taped interviews will be identified through this coding scheme.
- During the course of the research all tapes and transcribed interview data will be stored securely in files accessible to the researcher (Julia Fulton) only. These files will be held in a private office at the domicile of the researcher (Julia Fulton). Five people at Carleton will be exposed to these recorded and transcribed responses, the researcher and four thesis committee members.

Length of Interview Time:

The interview will take approximately 1.5 to 2 hours. If the interview subject agrees arrangements will be made to establish contact after the interview is completed for follow up questions.

Research Documents to be Produced From the Findings of This Research:

As a result of this research two documents will be produced. One document, the thesis, will outline a framework describing tacit knowledge transfer and transformation in new product development and how tacit knowledge may be leveraged in NPD. This framework will be developed as a result of a comparative analysis of the three firms participating in this research. One copy of the thesis, upon its completion will be forwarded to (Company Name). A summary of the thesis will also be produced and can be sent directly to the interviewees at their request.

If there are any questions please feel free to contact the researcher of this project at 299 – 4111 or by E: mail at fulto@magnum.ca.

Agreement to Participate in the Research Process:

Name of Interview Subject (please print)

Signature of interview subject

Signature of Researcher

Date

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

Thank you for your time,

Sincerely,

Julia Fulton
Graduate Student
Eric Sprott School of Business - Masters of Business Administration
Carleton University

Appendix A - 2**Interview Questions****Section 1 - Basic Personal Information**

- 1- Company name and address.
- 2- Interviewee's name and title.
- 3- Interviewee's Telephone number and e-mail address.
- 4- Interview location.

Section 2 - Background Information

To begin with, some questions about your background. This will provide an understanding of the sources of your tacit knowledge.

- 1- How long have you worked for (company name)?
- 2- What is your position and your key responsibilities?
- 3- What is your experience in NPD?
 - a. What type of new product development projects have been involved in:
 - continuous product development?
 - discontinuous product development?

Section 3 - Preliminary Questions**1. Understanding the new product development process of (company name):**

- a. please describe for me how the NPD process works in your firm,
 - how many phases are there?
 - what does each phase accomplish?
- b. briefly explain each phase.

If the NPD phases are not clearly defined within the company: (Refer to figure 4, Chapter 2), This diagram has seven phases: idea generation, product concept, design, development, prototype production, manufacturing and sales.

- a. Is the NPD process similar in your company?
- b. How should I change this diagram to visually represent the NPD process of your firm?
- c. Please briefly describe the NPD processes for me.

2- Understanding knowledge needs at each stage in the development of the new product:

- b. please describe for me how a new product is developed from idea generation to product launch.
- c. what are some of the main knowledge requirements at each phase in the NPD process?

Section 4a - Target Questions - These Questions Target Four of the Six Areas of Exploration on Tacit Knowledge Transfer and Transformation (see Targeted Areas of Qualitative Exploration, Chapter Four)

The four areas targeted are: the relative importance of tacit and explicit knowledge and the relative importance of different tacit knowledge types at each phase, an examination of when and how the transfer and transformation of tacit knowledge occur, an examination of the problems and barriers to effective tacit knowledge transfer and transformation, and an examination of the factors that enable the tacit knowledge transfer and transformation process.

Six main questions have been developed to provide data for the areas outlined above (there are also sub questions to these main questions). These questions will be asked to interviewees working in all NPD phases for each company.

Note: More specific questions tailored towards each NPD phase are provided next after this section.

General information about each NPD phase -

- ▶ What are the goals of this phase?
- ▶ Which people or groups are involved in this phase?
- ▶ How many people?
- ▶ What goes on in this phase?
- ▶ What information/knowledge is needed in this phase?
- ▶ Is tacit or explicit knowledge more important in this phase?
- ▶ Please describe what types of tacit or explicit knowledge are important to this phase.
- ▶ In general, how long does this phase take?

The transfer and transformation of tacit knowledge within each phase, achieved through the externalization and amplification of tacit knowledge -

- ▶ **How does the process of externalizing tacit knowledge occur?** - How is individual knowledge communicated to the group in the knowledge building process at each phase?
- ▶ **How does the process of tacit knowledge amplification occur?**
 - ▶ How is knowledge expanded/built on within group(s) at each phase?
 - ▶ How can the communication process be described in the knowledge building (amplification of tacit knowledge) process? Is it iterative? How frequently does the process of group divergence and convergence

- occur?
- ▶ What communication mediums are used in the knowledge building (amplification) process? Face to face, e-mail or other?
 - ▶ If meetings are used to conduct the knowledge building process, what are the structure of the meetings? Frequent, informal, cross function team involvement?

The transfer of tacit knowledge from one phase to the next - who are the senders and the recipients, and what are the processes and or mediums that achieve the transfer of tacit knowledge from one phase to the next -

- ▶ What knowledge is transferred from one phase to the next?
- ▶ To which individual(s) or group(s) is this knowledge transferred to?
- ▶ How is this knowledge transferred?
 - ▶ What does this transfer process look like? Is it transferred tacitly? How is it transferred tacitly? Is it transferred explicitly, how is it transferred explicitly?
- ▶ How is the continuity of the knowledge maintained between teams from one phase to the next?

Problems and barriers to the tacit knowledge transfer and transformation processes at each phase -

- ▶ Externalizing tacit knowledge - Are there problems with individuals communicating their ideas effectively to the team? What kind?
- ▶ Amplifying tacit knowledge - Are there problems with the knowledge building process, that is with individuals/teams effectively building on the knowledge of other individuals/teams? What kind?
- ▶ Transferring knowledge to the next team in the NPD cycle - Are there problems with the transfer of knowledge to the next phase? Are there problems with the continuity of the knowledge between phases and teams?
- ▶ Are there other knowledge problems other than those provided above?

In your opinion are there any solutions to the problems of the tacit knowledge transfer and transformation processes that you have just described?

What factors encourage the tacit knowledge transfer and transformation process at each phase -

- ▶ Do these factors relate to the selection of team members?
- ▶ Do these factors relate to processes which facilitate the communication process between team members?
- ▶ Do these factors relate to management style which facilitates the communication process between team members?
- ▶ Do these factors relate the degree of team trust which facilitates the communication process between team members?
- ▶ Do these factors relate to other reasons than those listed above?

Phase 1 - Idea Generation Phase

1 Please tell me how new ideas for products are generated.

Get the interviewee to elaborate on the following if possible:

1a General information about this idea generation phase/process -

- ▶ Do you have a process for brainstorming for new product ideas?
- ▶ What is the process for having a new idea considered?
- ▶ Who is involved in generating new ideas? Are there full time designated people who are involved in this process? Description of those individuals involved.
- ▶ Who decides which ideas are chosen and what criteria is used to chose the ideas that are further developed?
- ▶ what information/knowledge is needed in the process of developing new product ideas?
- ▶ Is it tacit or explicit knowledge more important for the idea generation process?
- ▶ Please describe what kind of tacit or explicit knowledge is important to the idea generation process.

1b Externalization and amplification of tacit knowledge during the idea generation phase-

- ▶ How and when a group formed after an idea has been chosen?
- ▶ Describe what this team does - what is the target goal of the team?
- ▶ **Externalization Process:** see if the interviewee can elaborate on how the ideas of an individuals (during idea generation) are communicated to the team, re: process of tacit knowledge externalization in this phase.
How is/are individual knowledge (ideas) communicated to the group during the idea generation phase?
- ▶ **Amplification process:** see if the interviewee can elaborate on how the group builds on these ideas, re: process of tacit knowledge amplification?
How is knowledge amplified within the team in this phase?
 - ▶ Describe the details of this communication process between team members. Is it iterative? Describe the process of team divergence and convergence?
 - ▶ What communication medium is used? Face to face, e-mail, other?
 - ▶ Tell me about the meeting process in this phase - if meetings, describe the structure of the meetings - informality, frequency, cross function involvement, or other?
 - ▶ There must be some meetings that go better than others, where ideas/knowledge are easily built on or expanded on within the team. Tell me about the characteristics of these types of meetings. **What makes it such that ideas are easily built on in team meetings in this phase?**

1c The transfer of tacit knowledge - to the next individual(s) or the next team(s) following the idea generation phase-

- **What does this transfer process look like?**
 - What knowledge is transferred to the next team/phase?
 - To which individual (s) or team (s) is this knowledge transferred to for further development?
 - How is this knowledge transferred? Tacitly or explicitly or both? How is it tacitly transferred? If explicitly, how it is transferred explicitly?
- How is continuity of the knowledge established from this phase to the next phase?

1d Problems and barriers to the tacit knowledge transfer and transformation processes in the idea generation phase -

- **What sort of problems are there that relate to the tacit knowledge transfer and transformation processes in the idea generation phase (pre-concept phase)?**
 - Externalizing tacit knowledge - are there problems with individuals communicating their ideas to the team effectively?
 - Amplifying tacit knowledge - are there problems effectively building on the knowledge within the team?
 - Are there problems with the transfer of knowledge to the next phase? Continuity of the knowledge?
 - Other knowledge related problems?

1e What are some of the solutions that you would recommend to solve some of these tacit knowledge transfer and transformation problems in the idea generation phase ?

1f What factors enable the tacit knowledge transfer and transformation processes of the idea generation phase?

- Do these factors relate to the selection of team members?
- Do these factors relate to processes which facilitate the communication process between team members?
- Do these factors relate to management style which facilitates the communication process between team members?
- Do these factors relate to the degree of team trust which facilitates the communication process between team members?
- Do these factors relate to other reasons than those listed above?

Phase 2 - Product Concept Phase

- 2 Please describe for me how new product concepts/ideas are further investigated.**
Refer to the following in the discussion: 1- investigating the product concept, 2- assessing the strategic fit, 3- evaluating the market opportunity, and 4- producing a preliminary project management report outlining the assumptions on cost and time.

2a General information about the product concept phase, investigating the product concept-

- ▶ **How are product concepts further investigated?**
 - ▶ How many people/teams are involved in this process?
Who/which teams are involved in this process?
Description of the individuals involved?
 - ▶ What information/knowledge is needed to investigate the product concept further?
 - ▶ Is this knowledge tacit or explicit?
 - ▶ Please describe what types of tacit or explicit knowledge are important to the product concept phase?
 - ▶ In general, how long does it usually take to investigate a product concept?

2b Externalization and amplification of tacit knowledge during the product concept phase-

- ▶ How is knowledge from the previous phase used/built on in the product concept phase?
- ▶ What new information is introduced/required in the product concept phase?
- ▶ **Externalization and amplification process:** see if the interviewee can elaborate on how knowledge is communicated and built on within the team during this phase. Also if analytical reports are developed then how is the knowledge externalized and amplified for the development of these reports?
 - ▶ Describe the details of this communication process between team members. It is iterative? Describe the process of group divergence and convergence.
 - ▶ What communication medium(s) are used? Face to face, e-mail, or other?
 - ▶ Tell me about the meeting process in this phase - if meetings, describe the structure of meetings - informality, frequency, cross function involvement, or other.
 - ▶ There must be some meetings that go better than others, where knowledge about the product concept is easily developed. Tell me about the characteristics of these types of meetings.

- 2c The transfer of tacit knowledge to the next phase following the product concept phase - to the next individual(s)/team(s) in the NPD process -**
- **What does this transfer process look like ?**
 - What information/knowledge is transferred to the next phase from this phase?
 - To whom is the information/knowledge in this phase transferred to for further development?
 - How is this information/knowledge transferred/communicated to the next group? Tacitly or explicitly or both? If tacitly, then how? If explicitly, then how?
 - How is continuity of the knowledge established from this phase to the next phase?
- 2d Problems and barriers to the tacit knowledge transfer and transformation processes in the product concept phase -**
- **What are some of the problems in the concept phase that relate to the tacit knowledge transfer and transformation processes?**
 - Externalizing tacit knowledge - what are the problems with individuals communicating their ideas to the team effectively?
 - Amplifying tacit knowledge - what are the problems effectively building on the knowledge within the team?
 - What are the problems with the transfer of knowledge to the next phase? Continuity of the knowledge?
 - Other knowledge related problems?
- 2e What are some of the solutions that you would recommend to solve some of these problems?**
- 2f What factors enable the tacit knowledge transfer and transformation processes of the product concept phase?**
- Do these factors relate to the selection of team members?
 - Do these factors relate to processes which facilitate the communication process between team members?
 - Do these factors relate to management style which facilitates the communication process between team members?
 - Do these factors relate to the degree of team trust which facilitates the communication process between team members?
 - Do these factors relate to other reasons than those listed above?

Phase 3 - Expanded Product Definition/Design Phase

- 3 Please describe for me how the product concept is transformed to the product designed.** Refer to the following in the discussion: 1- functional requirements product definition, 2- system level architecture design, 3- design planning, 4- test planning, 5- market planning, and 6- detailed project planning.
- 3a General information about the design phase/process-**
- ▶ **How is the product concept transformed to the expanded product definition and then to the product design in this phase?**
 - ▶ How many people/teams are involved in this process ?
 - ▶ Who/which teams are involved in this process ?
Description of the individuals involved.
 - ▶ What information/knowledge is needed to move the product concept to a product design?
 - ▶ Is this knowledge tacit or explicit?
 - ▶ Please describe what types of tacit and what types of explicit knowledge are important to the design phase?
 - ▶ In general, how long does it usually take to complete the design of the product?
- 3b Externalization and amplification of tacit knowledge during the design phase-**
- ▶ How is knowledge from the previous phase used/built on in the product design phase?
 - ▶ What new information is introduced/required in the design phase?
 - ▶ **Externalization and amplification process:** see if interviewees can elaborate on how knowledge is communicated and built on within the team during this phase. **How is knowledge externalized and amplified to produce the following: 1- functional and market requirements definition, 2- system level architecture design, 3- design planning, 4- test planning, 5- marketing and channel planning, 6- detailed project planning?**
 - ▶ Describe the details of the communication process between team members. Is it iterative? Describe the process of team divergence and convergence?
 - ▶ What communication medium is used? Face to face, e-mail, or other?
 - ▶ Tell me about the meeting process in this phase - if meetings, describe the structure of meetings - informality, frequency, cross function involvement or other?
 - ▶ There must be some meetings that go better than others in this phase, where knowledge about the expanded product analysis and definition is easily developed. Tell me about the characteristics of these types of meetings.

- 3c The transfer of tacit knowledge to the next phase following the expanded product definition and design phase - to the next individual(s)/group(s) in the NPD process -**
- ▶ **What does this transfer process look like?**
 - ▶ What knowledge is transferred to the next phase?
 - ▶ to whom is the information/knowledge in this phase transferred to for further development?
 - ▶ How is this knowledge/information transferred to the next group? Tacitly or explicitly or both? If tacitly, then how? If explicitly, then how?
 - ▶ How is continuity of the knowledge established from this phase to the next phase?
- 3d Problems and barriers to the tacit knowledge transfer and transformation processes in the expanded product definition/design phase -**
- ▶ **What are some of the problems in the design phase that relate to the tacit knowledge transfer and transformation process?**
 - ▶ Externalizing tacit knowledge - are there problems with individuals communicating their ideas to the team effectively?
 - ▶ Amplifying tacit knowledge - are there problems effectively building on the knowledge within the team?
 - ▶ Are there problems with the transfer of knowledge to the next phase? Continuity of the knowledge?
 - ▶ Other knowledge related problems?
- 3e What are some of the solutions that you would recommend to solve some of these problems?**
- 3f What factors enable the tacit knowledge transfer and transformation processes of the design phase?**
- ▶ Do these factors relate to the selection of team members?
 - ▶ Do these factors relate to processes which facilitate the communication process between team members?
 - ▶ Do these factors relate to management style which facilitates the communication process between team members?
 - ▶ Do these factors relate to the degree of team trust which facilitates the communication process between team members?
 - ▶ Do these factors relate to other reasons than those listed above?

Phase 4 - Development and Prototype Production Phase (see questions for Prototype Production next)

4 Please tell me how product development and testing is done for a new product.

4a General information about this phase/process -

▶ **How is product development and testing done?**

- ▶ How many people/teams are involved in this process?
Who/which teams are involved in this process?
Description of the individuals involved.
- ▶ What information/knowledge is needed to develop and test the product?
- ▶ Is this knowledge tacit or explicit?
- ▶ Please describe what types of tacit or explicit knowledge are important to the design phase?
- ▶ In general, how long does it usually take to complete the final development and testing of a product ?

4b Externalization and amplification of tacit knowledge during the design phase-

- ▶ How is knowledge from the previous phase/processes used/built on in the development phase?
- ▶ What new information is introduced/required in the development and testing phase?
- ▶ **Externalization and amplification processes:** see if the interviewee can elaborate on how knowledge is communicated and built on within the team during this phase. **How is knowledge externalized and amplified to produce the following: 1- software and hardware design, 2- test development, 3- material and build design, 4- process verification, 5- customer documentation, 6- training and course development, and 7- marketing channel management and support?**
 - ▶ Describe the details of the communication process between team members. Is it iterative? Describe the process of team divergence and convergence.
 - ▶ What communication medium is used? Face to face, e-mail, or other?
 - ▶ Tell me about the meeting process in this phase - if meetings, describe the structure of meetings - informality, frequency, cross function involvement or other?
 - ▶ There must be some meetings that go better than others in this phase. Tell me about the characteristics of these types of meetings.

4c The transfer of tacit knowledge to the next phase following the development phase - to the next individual(s)/teams(s) in the NPD process -

▶ **What does this transfer process look like?**

- ▶ What knowledge is transferred to the next phase?

- ▶ To whom is the information/knowledge in this phase transferred to for further development?
- ▶ How is this knowledge/information transferred to the next team? Tacitly or explicitly or both? If tacitly, then how? If explicitly, then how?
- ▶ how is continuity of the knowledge established from this phase to the next phase?

4d Problems and barriers to the tacit knowledge transfer and transformation processes in the development phase-

- ▶ **What are some of the problems in the product development and testing and verification phase?**
 - ▶ Externalizing tacit knowledge - are there problems with individuals communicating their ideas to the team effectively?
 - ▶ Amplifying tacit knowledge - are there problems effectively building on the knowledge within the team?
 - ▶ Are there problems with the transfer of tacit knowledge to the next phase? Continuity of the knowledge?
 - ▶ Other knowledge related problems?

4e What are some of the solutions that you would recommend to solve some of these problems?

4f What factors enable the tacit knowledge transfer and transformation processes in the development phase?

- ▶ Do these factors relate to the selection of team members?
- ▶ Do these factors relate to processes which facilitate the communication process between team members?
- ▶ Do these factors relate to management style which facilitates the communication process between team members?
- ▶ Do these factors relate to the degree of team trust which facilitates the communication process between team members?
- ▶ Do these factors relate to other reasons than those listed above?

Prototype Production

4 Please describe for me how prototype production is accomplished for a new product.

4a General information about the prototype production phase/process -

- ▶ **How is the prototype production accomplished for a new product?**
 - ▶ How many people/teams are involved in these processes? Who/which teams are involved in these process? Description of the individuals involved.
 - ▶ What information/knowledge is needed to complete the prototype production of the product?
 - ▶ Is this knowledge tacit or explicit?
 - ▶ Please describe what types of tacit and explicit knowledge are important to the prototype production?
 - ▶ In general, how long does it usually take to complete the prototype production phase?

4b Externalization and amplification of tacit knowledge during the prototype production phase-

- ▶ How is knowledge from the previous phase used/built on in the prototype production phase?
- ▶ What new information is introduced/required in the prototype production phase?
- ▶ **Externalization and amplification processes:** see if the interviewee can elaborate on how knowledge is communicated and built on within the team during this phase. **How is knowledge externalized and amplified to complete the prototype production?**
 - ▶ describe the details of the communication process between team members. Is it iterative? Describe the process of team divergence and convergence?
 - ▶ What communication medium(s) are used? Face to face, e-mail, or other?
 - ▶ Tell me about the meeting process in this phase - if meetings, describe the structure of meetings - informality, frequency, cross function involvement or other?
 - ▶ There must be some meetings that go better than others in this phase, where knowledge about prototype production for new products is developed easily. Tell me about the characteristics of these types of meetings.

4C The transfer of tacit knowledge to the next phase following the prototype production phase - to the next individual(s)/teams(s) in the NPD process:

- ▶ **What does this transfer process look like?**
 - ▶ What information/knowledge is transferred to the next phase from this phase?
 - ▶ To whom is the information/knowledge in this phase

transferred to for further development?

- ▶ How is this knowledge/information transferred to the next team? It is transferred tacitly or explicitly or both? If tacitly, then how? If explicitly, then how?
- ▶ How is continuity of the knowledge established from this phase to the next phase?

4d Problems and barriers to the tacit knowledge transfer and transformation processes in the prototype production phase -

- ▶ **What are some of the problems in the prototype production phase?**
 - ▶ Externalizing tacit knowledge - what are the problems with individuals communicating their ideas to the team effectively?
 - ▶ Amplifying tacit knowledge - what are the problems with effectively building on the knowledge within the team?
 - ▶ What are the problems with the transfer of tacit knowledge to the next phase? Continuity of the knowledge?
 - ▶ Other knowledge problems?

4e What are some of the solutions that you would recommend to solve some of these problems?

4f What factors enable the tacit knowledge transfer and transformation processes in the prototype production phase-

- ▶ Do these factors relate to the selection of team members?
- ▶ Do these factors relate to processes which facilitate the communication process between team members?
- ▶ Do these factors relate to management style which facilitates the communication process between team members?
- ▶ Do these factors relate to the degree of team trust which facilitates the communication process between team members?
- ▶ Do these factors relate to other reasons than those listed above?

Phase 5 and 6 - Manufacturing, Commercialization and Sales Phase

5 & 6

Please describe for me how manufacturing, commercialization and product sales are accomplished for a new product.

5a & 6a

General information about the manufacturing, commercialization and sales phase/process -

- **How are the manufacturing, commercialization and sales accomplished?**
 - How many people/teams are involved in these processes? Who/which teams are involved in these process? Description of the individuals involved.
 - What information/knowledge is needed to complete manufacturing, commercialization and sales of the product?
 - Is this knowledge tacit or explicit?
 - Please describe what types of tacit and explicit knowledge are important to the these activities?
 - In general, how long does it usually take to complete these activities?

5b & 6b

Externalization and amplification of tacit knowledge during the manufacturing and sales phase-

- How is knowledge from the previous phase used/built on in the manufacturing, commercialization and sales phase?
- What new information is introduced/required in the manufacturing, commercialization and sales phase?
- **Externalization and amplification processes:** see if the interviewee can elaborate on how knowledge is communicated and built on within the teams for these activities. **How is knowledge externalized and amplified to prepare for these activities?**
 - describe the details of the communication process between team members. Is it iterative? Describe the process of team divergence and convergence?
 - What communication medium(s) are used? Face to face, e-mail, or other?
 - Tell me about the meeting process in this phase - if meetings, describe the structure of meetings - informality, frequency, cross function involvement or other?
 - There must be some meetings that go better than others in this phase, where knowledge about manufacturing and commercialization for new products is developed easily. Tell me about the characteristics of these types of

meetings.

5c & 6c

The transfer of tacit knowledge to the next phase- to the next individual(s)/teams(s) responsible for the continuous improvement of the product:

- **What does this transfer process look like?**
 - What information/knowledge is transferred to the next phase from this phase?
 - To whom is the information/knowledge in this phase transferred to for further development?
 - How is this knowledge/information transferred to the next team? It is transferred tacitly or explicitly or both? If tacitly, then how? If explicitly, then how?
- How is continuity of the knowledge established from this phase to the next stage?

5d & 6d

Problems and barriers to the tacit knowledge transfer and transformation processes for manufacturing, commercialization and sales phase -

- **What are some of the problems in the manufacturing, commercialization and sales phase?**
 - Externalizing tacit knowledge - what are the problems with individuals communicating their ideas to the team effectively?
 - Amplifying tacit knowledge - what are the problems with effectively building on the knowledge within the team?
 - What are the problems with the transfer of tacit knowledge to the next phase? Continuity of the knowledge?
 - Other knowledge related problems?

5e & 6e

What are some of the solutions that you would recommend to solve some of these problems?

5f & 6f

What factors enable the tacit knowledge transfer and transformation processes in the manufacturing, commercialization and sales phase-

- Do these factors relate to the selection of team members?
- Do these factors relate to processes which facilitate the communication process between team members?
- Do these factors relate to management style which facilitates the communication process between team members?
- Do these factors relate to the degree of team trust which facilitates the communication process between team members?
- Do these factors relate to other reasons than those listed above?

Phase 7 - Continuous Improvements to New Products

7 Please tell me how continuous improvements are made to new products.

7a General information about this process -

- ▶ **How are suggestions for improvements to new products generated ? Please take me through this process?**
 - ▶ Where do these suggestions come from?
 - ▶ Who is involved in this process? Description of those individuals involved.
 - ▶ Who decides what improvements will be included in each generation of the product ?
 - ▶ What criteria is used to govern whether these improvements will be implemented?
 - ▶ What information/knowledge is needed to make continuous improvements to new products.
 - ▶ Is this knowledge tacit or explicit?
 - ▶ Please describe what types of tacit and explicit knowledge are important to the continuous improvements process?
 - ▶ In general, how long do next versions of the new product take to complete?

7b Transfer of tacit knowledge from clients/dealers on 1st generation of the new product-

- ▶ **How is the knowledge (client/dealer feedback) communicated/ transferred to the teams(s) who make the design/technological changes/improvements?**
 - ▶ Is this knowledge/information (feedback) transferred to this team tacitly or explicitly or both? If tacitly, then how? If explicitly, then how?
 - ▶ In the knowledge transfer processes to these technological/design groups, some meetings go better than others, why?

7c Externalization and amplification of tacit knowledge during the continuous improvements process: see if the interviewee can elaborate on how knowledge is communicated and built on within the teams during this process.

- ▶ Describe the details of the communication process between team members. Is it iterative? Describe the process of team divergence and convergence.
- ▶ What communication medium(s) are used? Face to face, e-mail, or other?
- ▶ Tell me about the meeting process in this phase - if meetings, describe the structure of meetings - informality,

- frequency, cross function involvement, or other?
- ▶ There must be some meetings that go better than others, during this process. Tell me about the characteristics of these types of meetings.

7d The transfer of tacit knowledge between teams(s) who carry out continuous improvements to the product -

- ▶ What teams are involved in technological/design changes to be made to existing products?
- ▶ How does the transfer of tacit knowledge occur between these teams?
- ▶ How is this knowledge/information transferred between teams, tacitly or explicitly or both? If tacitly, then how? If explicitly, then how?
- ▶ How is continuity of the knowledge established for next generations products such that the understanding of technological know how is not lost?
 - Is it transferred to a data base?
 - ▶ What kind of data base is it transferred to?
 - ▶ What information is codified in the data base?
 - ▶ How is this codified knowledge used in the future?

7e Problems and barriers to the tacit knowledge transfer and transformation process during the continuous improvements process-

- ▶ **What are some of the problems with the process of making continuous improvements to new products?**
 - ▶ Are there problems with the communication/feedback process from clients and dealers?
 - ▶ Are there problems with the transfer of knowledge between the recipients of client/dealer feedback and the team that makes the design/technological changes?
 - ▶ Have there been problems with insufficient or poor quality of product knowledge transferred from the NPD team?
 - ▶ Problem of not codifying enough of the new product technological know-how during the NPD process?
 - Problem with losing design/technological know-how because employees leave?
 - ▶ Lack of design documentation standards, therefore difficulty understanding the code that has been written.

7f What are some of the solutions that you would recommend to solve some of these problems ?

7g What factors enable the tacit knowledge transfer and transformation process during the continuous improvements process?

7h Other Issues in this process -

- ▶ How do new teams / new employees involved in the improvements/changes process acquire all of the necessary

- information/knowledge on the product ?
- Where is this product information kept? Is the information shared universally?

Section 4b - Target Questions - These Questions Target Two of the Six Areas of Exploration on Tacit Knowledge Transfer and Transformation (see Targeted Areas of Qualitative Exploration, Chapter Four)

The two areas targeted are: team composition and the degree of team trust and its effect on the tacit knowledge transfer and transformation process within the NPD team.

These questions will confirm or refute two hypothesis outlined earlier in Chapter Three, pertaining to the affect of team heterogeneity and homogeneity, team shared mental models and team trust on the tacit knowledge transfer and transformation processes (Chapter Three for hypothesis 2a, 2b and 3).

Questions:

- 1- Can you think about a new product development project that was successful.
 - 1a - Can you give me some background information on this project?
 - 1b- Why was this project successful?
 - 1c- What are some of the factors that made this project successful?
 - If completed on time, what were the factors which helped to have it completed on time?
 - was it because communication between team members was good? Tell me about the communication process between team members.
 - How were individual ideas communicated effectively to other team members?
 - How were ideas built on effectively by team members?
 - If the product met the needs and cost of the targeted customer, then what factors helped to have this happen?
 - Was it because the communication between members was good? Tell me about the communication process between team members.
 - How were individual ideas communicated effectively to other team members?
 - How were ideas built on effectively by team members?
 - Other?

2- The section focuses on the selection of team members (re: similar or dissimilar knowledge sets and shared mental models within a team) in facilitating or hindering the externalization and amplification of tacit knowledge within a team.

- 2a- Who were the team members in this project?
 - 2b- What were their backgrounds and level of experience?
 - 2c- Did these people work together before? How many worked together before?
How much shared common knowledge did they have?
 - 2d- Do you think that team members selection is crucial to the outcome of the new product? Why?
 - 2e- Do you think the that team members that have similar or dissimilar knowledge sets helps or hinders the communication and/or knowledge building process within the team? Please provide some examples.
 - 2f- Do you think that team members that have shared mental models helps or hinders the communication or knowledge building process? Please provide some examples.
 - 2f- When does a team build effectively and efficiently on each other ideas? Can you recall a situation when this happened? Please describe for me why this team was able to effectively and efficiently build on each other ideas? Did it have anything to with their backgrounds or their shared prior work experiences?
 - 2g- When does a team become difficult to manage? Can you recall a situation when a team was difficult to manage? Please describe for me what happened.
- 3- This section is concerned with the level of trust within a team to facilitate or hinder the externalization and amplification of tacit knowledge among and between team members.
- 3a- Getting back to the example of the successful project that you were talking about before. Was the trust factor high in the team?
 - 3b- How do you define trust?
 - 3c- How was the trust fostered in this team?
 - 3d- Do you feel that trust is critical in the successful outcome of a new product being developed? How critical is it?
 - 3e- How can (company name) improve the level of trust in NPD team environments?
- 4- Tell me about an unsuccessful project
- 4a - Can you give me some background information on this project.
 - 4b- Why was this project unsuccessful?
 - 4c- What are some of the factors that made this project unsuccessful? Please comment on the following:
 - Communication: how did the team communicate? Where did the problem(s) lie within the team's communication?
 - The level of trust between team members: how much trust did the team members have with their team mates. How would you describe trust in this situation?
 - Shared mental models between team members: was there not enough shared prior knowledge or shared understanding between group members?
 - Knowledge sets: there were certain disciplines missing from the core NPD development team? Was there were too many different knowledge sets in the core NPD team?

Section 5 - Questions for Interview Participants with Indirect Supporting Role to the NPD Process

- 1- How does your group play into the NPD process? In what ways does your group help the NPD process?
- 2- Please explain to me in detail what your group does?
 - Explain to me what your groups's goals are.
 - Explain to me what you do in your group.
- 3- How many people are in your group?
 - Who are these people and what are their positions?
- 4- What knowledge/information does your group produce?
- 5- Who are the receivers of your group's knowledge?
- 6- How does your group generate their knowledge?
 - **Tacit Knowledge Externalization and amplification process:** How is the knowledge in your group generated?
 - **Tacit Knowledge Externalization:** How do group members communicate to the rest of the group and how do other group members build on it? Please describe this process.
 - There are times when the generation of knowledge in your group works well and times when it does not work well. Please describe why this may be the case.
- 7- In what way is this knowledge communicated to the receivers of your group's knowledge?
 - is it passed on tacitly, explicitly or a combination of both.
 - If tacitly transferred, then describe the tacit knowledge transfer process.
 - Was the communication process iterative? Describe the process of convergence and divergence.
 - Describe the structure of the meeting: informality, frequency, group members present.
 - If explicitly transferred, then what communication medium was used?
 - **Tacit knowledge Amplification:** How do the recipients of your groups knowledge build on the knowledge that is transferred?
 - If meetings then describe the structure of meetings used: informality, frequency, group member involvement.
- 8- In the knowledge transfer processes of your group's knowledge to other groups, some transfer processes/meetings go better than others, why?
- 9- How is continuity of your group's knowledge ensured?

- 10- What are the problems with the knowledge transfer processes to other groups?
- 11- What are some solutions to these problems ?
- 11- Do you feel that trust is an important part of your group's success ? How important is it ?
- 12- How is trust achieved in your group ?
- 13- Please describe for me an outcome of a request for knowledge that was deemed as successful in your group.
 - How many group members at that time?
 - What were their (knowledge) backgrounds?
 - How many of the group members had worked together previously.
 - Do you think that trust between group members was the reason for the success? How would you describe this trust?

Section 6 -Tacit Knowledge Audit

Do you think that some of the success of knowledge generation and transfer in your firm and in your department would improve if there was a change in the following and why ?

- a. If the organizational climate were different ? If senior management were more caring - yes/no? If top management were more open - yes/no ?
- b. If the organizational structure were different ? Less hierarchy - yes/no? If your department structure was physically more open - yes/no?
- c. If the nature of meetings changed ? More face to face interaction - yes/no, more informality - yes/no, better management of the meeting process - yes/no?
- d. If the company encouraged the sharing and exchange of knowledge? through mentoring programs - yes/no? Social programs - yes/no? Other programs - Yes /no?
- e. If there were incentive systems which provided financial rewards and other rewards - yes/no ? Rewards for the sharing and the dissemination of knowledge - yes/no?
- f. If managers managed differently - yes/no?
- g. If top management support were different - yes/no?

Please rate your company in the following areas:

1 agree.....5 strongly disagree

1- My company has a caring organizational climate. 1, 2, 3, 4, 5

2a- The organizational design in our department is open. 1, 2, 3, 4, 5

2b- There is virtually no hierarchical structure in our organization. 1, 2, 3, 4, 5

3a- We have incentive systems in place that provide rewards for people who actively mentor. 1, 2, 3, 4, 5

3b- We have incentive systems in place that provide rewards for people who openly and actively share knowledge. 1, 2, 3, 4, 5

4- Your team leaders tend to have what is called A shaped skills, that is individuals who have learned more than one discipline. 1, 2, 3, 4, 5

5- Team members tend to have what is called T - skills, that is individuals who are not only experts in specific technical areas but who are also intimately acquainted with the potential systemic impact of their particular tasks on others. 1, 2, 3, 4, 5

6- Team leaders can effectively manage the creative differences/creative conflict of individuals with in a team environment. 1, 2, 3, 4, 5

7- Team leaders encourage respect for different thinking styles. 1, 2, 3, 4, 5

8- Team leaders place a high importance on mentoring and assisting others. 1, 2, 3, 4, 5

9- Top management supports our initiatives/new product ideas. 1, 2, 3, 4, 5

10- Our management or team members often make use of sketches, drawings, anecdotes, examples and storytelling to transfer new ideas. 1, 2, 3, 4, 5

11- Most of the communication between team members in our firm takes place face to face, frequently and informally. 1, 2, 3, 4, 5

12- We often have emotional based disagreements in our group when problem solving. 1, 2, 3, 4, 5

13- Many of the team members in our group have the same educational background, experience. 1, 2, 3, 4, 5

14- Trust in technical competence in our teams is high. 1, 2, 3, 4, 5
 Technical competence refers to the reciprocal faith that members have in one another to

complete the tasks in their area of expertise successfully either by involving themselves or other suitable persons.

15- Performance reviews are based on team performance. **1, 2, 3, 4, 5**

16- Performance appraisals emphasize helping behavior towards others. **1, 2, 3, 4, 5**

17- Employees are hired based on their ability to communicate in a group settings. **1, 2, 3, 4, 5**

Appendix B-1

Soft-Co Analysis
Responses Exploration and Proposition Investigation

Soft-Co
NPD Process Overview

Verifying Proposition No. 1 - Soft-Co

This proposition examines the relative emphasis on tacit and explicit knowledge, and the relative emphasis on different tacit knowledge types through NPD Phases.

Verifying Proposition 1a: verifying the use of tacit versus explicit knowledge at each phase in the NPD process of Soft-Co.

Phase	Tacit Versus Explicit Knowledge	Explanation of Breakdown
Phase 1 - Idea generation	approx. 95 % tacit, 5 % explicit	Many new product ideas within Soft-Co have come largely from the tacit knowledge bases of very senior R & D people. These individuals have a good understanding of the tone and direction of new product development set forth by the Business Development Team of the company and also a good understanding of customer problems and needs. Many of these individual have been with the company for over 20 years, naturally they have very high levels of expertise and experience (tacit knowledge) that are used in the development of new product ideas.
Phase - Investigation	approx. 70 % tacit, 30 % explicit	A team of 4 or 5 individuals, further investigate the product concept by identifying the market in greater detail, assessing key differences with competing products and defining at a high level the product and key requirements. Much of this investigation and creating the high level definitions come largely from tacit input of the members of the investigation team. In general these members tend to be quite senior and highly experienced. Some marketing information, explicit knowledge, is required to complete the investigation in this phase.

Phase 3 - Prototyping	80 % tacit, 20 % explicit	Several senior software engineers join in the prototyping phase to iron out the bare structure of the software design. These designers are not working from specifications but in effect designing the specifications. Separate product pieces are designed separately at first. This prototyping design process for each product piece is guided by initial objectives but then remains quite loose to allow software engineers to design based on what their intuition and experience tells them. A good deal of tacit knowledge goes into the design process at this phase. Their work is highly iterative. Ideas are sent back and forth in many informal face to face meetings between team members within the same product piece.
Phase 4 - Integration	50 % tacit, 50 % explicit	This phase involves the development of the product from the prototype design. This involves mainly the integration of separately designed product pieces and the services of the firm. Less flexibility and more process usually come into play at this phase. Product Management, UI (user interface group), documentation, Quality Assurance and the field Software Specialists all contribute to the validity and stability of the product design. Much of the skill needed to provide this input are tacitly based however the prototype design has been documented and can now be considered explicit information. Soft-Co typically begins the design documentation process after the first prototype has been produced.
Phase 5 - Commercialization	approx. 35 % tacit, 65 % explicit	The main activities of this phase are the implementation of the marketing plan, sales training (some of the sales training has been accomplished during the development phase) and the distribution of the product. These activities occur through the aid of explicitly documented plans, although a component of tacit knowledge is required in carrying out these plans and procedures.

Plotting the results of our findings for explicit/tacit knowledge use at Soft-Co:

Proposition 1b: Verifying the use of contextual versus technical tacit knowledge at each phase in the NPD process of Soft-Co.

Phase	Contextual versus Technical Tacit Knowledge	Explanation of Breakdown
Phase 1 - Idea generation	approx. 30 % contextual, 70 % technical	<p>New product Ideas are predominantly driven through senior people within the development organization of Soft-Co. Many of these individuals have been with the company for over 20 years. These individuals have very high levels of technical tacit, they also have relatively high levels of contextual tacit knowledge, that is an understanding of the goals and the strategic direction of the firm and a good understanding of customer needs and expectations. Historically some of Soft-Co's ideas have been developed in an attempt to solve a particular customer problem but the base of idea development is still predominantly technically driven and therefore have required large amounts of technical tacit knowledge to be derived.</p>
Phase 2 - Investigation	approx. 50 % contextual, 50 % technical	<p>More effort at this phase goes into investigating the product idea. Assessing the market, the competing products within the market and creating a high level product definition. These require the use of contextual and technical tacit knowledge. Technical tacit knowledge is used in creating the high level technical product definition, and in assessing the technical differences of competing products. Contextual tacit is used in assessing the market and also in assessing the difference between competing products from a customer needs perspective. Both types of tacit knowledge are equally important to accomplishing the objectives of this phase.</p>

Phase 3 - Prototyping	approx. 25% contextual, 75 % technical	Several senior software engineers join in the prototyping phase to iron out the bare structure of the software design. A large amount of technical tacit goes into the design process because these designers are not working from specifications but in effect designing the specifications. Product management often comes into this phase to filter customer requirements into the design process. A contextual tacit skill set is used to assess the feedback from customers and communicate these requirements.
Phase 4 - Integration	approx. 30 % contextual, 70 % technical	This phase involves the development of the product from the prototype design. Product management, UI (user interface group), documentation, Quality Assurance and Software Field Support. Much of the skill needed to integrate these areas into the product are technically tacit based skill sets. Some are contextually tacit based. For example, marketing begins to develop a marketing platform at this phase.
Phase 5 - Commercialization	approx. 75% contextual, 25% technical	The main activities of this phase are the implementation of the marketing plan, sales training and the distribution of the product. Many of these activities require contextual tacit based skills. The sales training requires the transfer of some explicit and tacit technical knowledge. Some technical tacit knowledge is also used during the sales pitch of the product to customers.

Plotting the results of our findings for contextual/technical tacit knowledge use at Soft-Co.

Proposition no. 1 is not validated by the data collected from Soft-Co. The proposition states that there is a strong presence of contextual tacit in the beginning and end phases. This argument was validated in all phases except within phase 1 and phase 2 of the NPD process.

The model outlined in the proposition at phase one - idea generation, reflects product ideas that come largely from the marketing organization of the company or reflects the strong influence of marketing in the early development of the idea. Although Soft-Co incorporates some of the needs of the customer into the reason d'être behind new product ideas, it is the ideas and the influence of the development organization that carry more weight in this idea generation and investigation phase.

Exploratory Question 1 - Soft-Co

This question explores when, by whom and how the transfer and transformation of tacit knowledge occur in the NPD processes of Soft-Co.

Phase 1 - Idea Generation

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

Historically, new product ideas within Soft-Co have come mostly from senior people within the development part of the organization. These people tend to be highly experienced engineers and have been with the company for many years (over 20 years). Working from little explicit direction, externalization and amplification of tacit knowledge are important to the objectives of this phase. For example one new product idea came as a result of the Company's need to replace a product that was losing the greatest amount of market share. From this, one senior person in the New Products Division proposed a new software solution that could potentially fill the needs of customers within this target market.

2) Who - The composition of NPD teams at this phase:

- ▶ The Business Development Team - responsible for setting the tone and direction of NPD initiatives.
- ▶ Senior people (engineering background) mainly within the New Products Division of the organization.

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each stage:

- ▶ Co-located - The Business Development Team and NPD are situated within the same building.
- ▶ Communication process - Both formal and informal communication took place between these individuals (NPD) and the Business Development Team.
- ▶ Externalization tool used - Many new product ideas within Soft-Co are demonstrated to the Business Development Team in less than prototype format. Code is used to present the bare bone idea.

Phase 2 - Investigation

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

The objectives of this phase are to expand the product idea from the idea generation phase and produce a more solid, high level technical and marketing product definition. Also this phase is used to assess the differences with competing products and the market opportunity. Tacit knowledge externalization and amplification are important to the objectives of this phase. Most the knowledge used is still mostly tacit based and a team consensus must be reached on the product definition—requiring transformation of tacit knowledge. Some explicit research, marketing research is amplified in this phase. Some of the individuals of the investigation phase continue designing and developing the product through the remaining NPD phases.

2) Who - The composition of the NPD team at this phase:

- ▶ Investigation Team - Approximately 4 or 5 individuals, usually a mixture of senior developers, architects and marketing people

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each phase:

- ▶ Co-located - All individuals within the NPD division are co-located. Usually located on the same floor of the same building.
- ▶ Communication process - Much of the analysis needed to investigate the product concept is typically accomplished through frequent, informal and face to face interaction.
- ▶ Externalization tool used - Many visuals are used to presented and provide an understanding of the new product idea.

Phase 3 - Prototyping

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this stage:

Tacit knowledge externalization and amplification are highly important processes to the objectives of this phase. The bulk of software design innovation occurs at this phase, where the first level design of the software product is ironed out through small teams responsible for pieces of the product. The knowledge building process within this phase can be described mostly by the repetitive externalization and amplification of tacit knowledge that occurs through frequent, informal and iterative face to face interactions until the prototype of each product piece is complete.

The requirements document outlining requirements for the product is used to development the prototype. Initially the requirements document gets written by Product Management but then is also amplified by marketing and development who also provide input into the requirements of the product.

2) Who - The composition of the new products team at this phase:

- ▶ The total number of people in this phase is dependant on the number of product pieces, typically this number is anywhere between 20 and 30 people. 2 - 3 people are often responsible for the prototype development of each product piece.

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each phase:

- ▶ Co-located - All persons responsible for the prototype development of the product pieces are co-located and so much of the communication process occurs informally between team members.
- ▶ Communication process - occurs through highly iterative frequent, informal and face to face interactions until the prototype of each product piece is complete.
- ▶ Externalization tools used - whiteboard, brainstorming

Phase 4 - Implementation

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this stage:

Tacit knowledge externalization and amplification are somewhat important to the objectives of this phase (less important than previous phases). The main objective of this phase is the development of the product from the prototype design. This is accomplished by integrating the various product development pieces and ensuring the quality of the product through input from the User Interface group (UI), Quality and Assurance group (QA), Software Field Support and documentation. The knowledge building process within this phase become mainly an amplification process. Most of the tacit knowledge required to build the product has already been externalized and explicitly documented by the prototype team, although many informal discussion take place between design and these groups where tacit knowledge about the prototype design is exchanged. These groups outlined above amplify the explicit and tacit knowledge of the prototype group by improving the final quality of the product.

The externalization and amplification process between design and quality assurance is accomplished through the use of a software package called tracker and also through co-location of the two groups. Unlike many firms these two groups are a part of the same team and are co-located at Soft-Co. Many of the problems found during testing and verification are formally logged onto the tracking device and usually also communicated informally through face to face discussions.

2) Who - The composition of the New Products Team at this phase:

- ▶ Development
- ▶ User Interface Group (UI)
- ▶ Quality and Assurance Group (Q & A)
- ▶ Software Field Support Specialists (SS)
- ▶ Documentation

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each phase:

- ▶ Co-located - All of these groups are situated within the same building. Quality Assurance and development are part of the same team and have cubicles which are co-located.
- ▶ Communication process - Formal and informal face to face, e-mail, telephone interaction. Weekly status meetings, bi monthly integration meetings
- ▶ Externalization Tools used - Visuals, whiteboard, brainstorming, the process of writing - documenting

Phase 5 - Commercialization

<p>1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:</p> <p>Tacit Knowledge externalization and amplification are not as important to this phase as in previous phases. The marketing of the product occurs mainly through plans previously outlined in former phases and now being carried out. Tacit input is required to develop these new processes.</p>
<p>2) Who - The composition of the core and the extended team members of this phase:</p> <ul style="list-style-type: none"> ▶ Marketing ▶ Soft-Co Sales Force
<p>3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each phase:</p> <ul style="list-style-type: none"> ▶ Co-located - not co-located. Global sales force and global marketing. ▶ Communication process - E-mail, telephone, some face to face interaction ▶ Externalization methods - Unknown

Exploratory Question 2 - Soft-Co

This question explores issues that might account for why the tacit knowledge transfer and transformation process might not go the way it should, and also the types of tacit knowledge that are typically not transferred into the NPD process but are argued to be important.

Description of Problem	How this Problem hinders the Transfer and transformation of Tacit Knowledge - The Knowledge Building Process
<p>1) Lack of Marketing Content: Marketing needs to be integrated more into the development process.</p> <p>Suggested: A product manager should be placed in marketing.</p> <p>A general recommendation that would solve part of this problem: a senior marketing person who really understands business intelligence market, how to craft it up into pieces and how to define products to attack those portions of the market.</p>	<p>The wrong knowledge may get amplified in the knowledge building process. As a result of this several products have missed the market, and products have been introduced for which there is no market.</p>

2) There is a tendency to integrate marketing, the customers and the field support too late in the NPD process. More formalized channels of knowledge transfer may help to facilitate the integration of these knowledge types.	The wrong knowledge may get amplified in the knowledge building process. Features or requirements may be missing or unnecessarily built into the product.
3) A need for more of the development organization of Soft-Co to understand how to look for business software solutions that solve a particular business problems. This requires more effort to understand first hand customers processes and problems.	If all NPD members are on the same page, then tacit knowledge externalization and amplification processes are facilitated.
4) There is a need to develop more process and build more infrastructure to facilitate the transfer of important knowledge (tacit and explicit). Another problem with having no formal process is a lot of little different informal processes exist that change from person to person. This presents a problem when assessing the effectiveness of NPD.	Process or infrastructure can facilitate the transfer of knowledge needed so that the correct knowledge is amplified in the knowledge building process.
4) A lack of communication exists between groups. There are no mechanisms in place that facilitate the transfer of knowledge between independent technology groups. In some cases the same type of code has been written in two different places of the company. This code could have been shared. This is often the by product of a company that has diverse products like Soft-Co.	The transfer of knowledge between independent technology groups within Soft-Co can facilitate the knowledge building process.
5) Organizationally Soft-Co has allowed many senior people to become single technical resources with knowledge in critical technical areas.	If these people leave then prime tacit technical resources are lost .
6) Documents are sometimes written and thrown over the wall. Many of the key documents should be presented by the author.	This would facilitate greatly the externalization and amplification of tacit knowledge.
7) No documentation guide lines exist at Soft-Co. As a result of this a hodgepodge of documentation process exist that can make understanding existing design or code difficult. Suggestion: Need to standardize the documentation process but not to the degree that it will negatively impact the development process.	Makes the amplification of tacit knowledge very difficult.
8) No process exists within Soft-Co for growing certain areas of know-how (tacit knowledge) within the development organization.	Makes the development of technology in certain areas difficult.

9) It is often difficult finding pieces of information when you need them. What is needed is a better overall information tree where information about other groups and components in the company are easily accessible.	Facilitates the knowledge building process.
10) Limited social activities at Soft-Co	Social activities often enables knowledge sharing and of course facilitates the externalization and amplification of tacit knowledge.
11) Greater need to create avenues for know-how (learning) and knowledge transfer between project managers, where PM lessons are shared, discussed and learned.	Facilitates the knowledge building process.

NPD Phase	Description of Problem	How this Problem hinders the Transfer and Transformation of Tacit Knowledge - The Knowledge Building Process
Phase 1 - Idea Generation		
Phase 2 - Investigation	1) Greater efforts need to be put into the feasibility study - No formal process exists for identifying markets for size and revenue.	Missing knowledge.

Phase 3 - Prototyping	<p>1) People don't write down what they are doing. It is in their heads and they are not always externalizing it. One or two people are really driving the design process, and how do we share that is the largest challenge.</p> <p>2) For many of the new products there has been a lack of clear functional requirements. Product management needs to come into the design process earlier. Need to be more involved in the design making process to ensure correct implementation of features.</p> <p>3) Marketing does not get involved in the NPD process until the prototype has been designed, half way through this stage or sometimes not until the next stage.</p>	<p>In the prototyping phase there are often difficulties with not writing enough of the specifications as the design is being worked out. Important information about the prototype design may be misunderstood or missed altogether when the product is further developed.</p> <p>The wrong knowledge may get amplified in the knowledge building process. Features or requirements are either missing or unnecessarily built into the product.</p> <p>Marketing input is needed to assess marketing opportunities and customer needs and expectations.</p>
Phase 4 - Implementation	<p>1) Need for greater customer involvement in the testing and verification environment. Without this information it can be difficult to know who is going to use the product or even how they may use it if there is no customer involvement or lack of customer involvement. Q and A business analysis often falls short with the business model analysis because of this lack of customer involvement.</p> <p>2) From Q and A perspective the markets requirement document is too general. More detail is needed to properly test the product.</p> <p>3) NPI process - The structure is vague between development and Q and A in the NPI process. For example, development may have different coding practices from Q and A.</p>	<p>Missing knowledge.</p> <p>Missing knowledge</p>

Phase 5 - Commercialization	1) The Field Software Specialists are often being trained when Beta has already taken place. As result of this they often have less knowledge than the customers by the time the product is available for sale.	Missing knowledge
-----------------------------	---	-------------------

Exploratory Question 3 - Soft-Co

This question explores factors that enable the transfer and transformation of tacit knowledge.

Interviewees at Soft-Co has suggested several factors:

- ▶ Too many members on a team make good communication difficult—problems with externalizing and amplifying are high. Because of this it is recommended that teams be small in size during the NPD process. Recommended size, not more than 4- 5 people building product pieces.
- ▶ NPD structure should be loose. Often when process is incorporated in the initial software development phases the innovation (tacit knowledge transfer and transformation) is hindered.
- ▶ Experienced members of a team often facilitate the tacit knowledge transfer and transformation process, however, if members are lacking in experience then process is needed to facilitate the transfer of knowledge during the development cycle.
- ▶ Physically isolating the new product development team facilitates the transfer and the transformation of tacit knowledge. Fewer distractions enables clear communication between team members, hence tacit knowledge transfer and transformation are facilitated.
- ▶ Encouraging the team members to own the product. Owner ship of the product by team members makes members accountable for the outcome of their development efforts. As a result of this, communication between team members usually becomes very free and frequent, tacit knowledge is more easily transferred.
- ▶ Placing effort into building a highly motivated and enthusiastic team. Tacit knowledge automatically spreads between team members within a team where members are enthusiastic.
- ▶ Making sure that there is a project champion to champion the new product development effort. Product champions believe in their product development efforts. This belief is usually transferred to other members and usually encourages communication between team members.
- ▶ Co-location of NPD members - Co-location of team members facilitates informal, frequent and face to face communication between team members.
- ▶ Make sure that the key people on the new products team are the same people from the beginning of the cycle to the end. This facilitates tacit knowledge transfer, which seems to facilitate the continuity of knowledge.
- ▶ Paralleling some NPD process provides avenues in which to create tacit knowledge transfer loops between NPD functions, design and development, software support training, and

- documentation. Knowledge transfer loops enable greater quality product design and training.
- ▶ Ensuring that Development and Quality and Assurance are a part of the same group. Communication between these groups can at times be difficult because of the nature of testing and verifying. Making these two groups a part of the same team facilitates the tacit knowledge transfer between these two groups. At Soft-Co these two functions of product development are co-located. Although product problems are logged by Q and A, they are for the most part solved through face to face discussion.
 - ▶ Ensuring that the same pay scale is used for Q and A and Development encourages team members to view both development and Q and A with the same importance and also facilitates relations between the two product development functions, which also seems to facilitate tacit knowledge transfer and transformation.
 - ▶ Hiring Quality and Assurance Analysts who have direct experience with the product to ensure quality and accurate testing of the product. For example Soft-Co S hired several Q and A analysts with accounting experience (one new product being developed was an accounting based software package).

Appendix B-2

Comm-Co Analysis
Responses to Exploration and Proposition Investigation

Comm-Co
NPD Process Overview

Verifying Hypothesis No. 1 - Comm-Co

Verifying Proposition 1a: verifying the use of tacit versus explicit knowledge at each phase in the NPD process of Comm-Co.

Phase	Tacit versus Explicit Knowledge	Explanation of breakdown
Phase 1 - Pre-concept	approx. 80 % tacit, 20 % explicit	The development of an idea comes mostly from tacit knowledge, through very experienced engineers. But the product idea in Comm-Co must be approved by a senior committee before it can proceed to the next development phase. The committee analyzes the idea based on the strategic direction of the company and the business opportunity it provides, some of which is based on explicit information.
Phase 2 - Concept	approx. 75% tacit, 25 % explicit	The concept team further investigates this product concept. The concept team relies heavily on a skill set that has them providing a high level assessment of the product concept. The assessment skill set and the innate ability to communicate and share ideas well, much of it is tacit based. This phase does use some explicit information, typically market research.
Phase 3 - Analysis	approx. 60 % tacit, 40 % explicit	The core team members are present in the analysis phase to validate the assumptions in the concept analysis brought forth by the Concept Team. Focus is place on a technical and business analysis in this phase. Although analysis skills are tacitly based, this phase also has strong information needs required to validate the assumptions made by the Concept Team. These explicit information needs are: market trends, market segment research and competitive and costing information.

Phase 4 - Implementation	approx. 50 % tacit, 50 % explicit	This phase involves the implementation of the project plan through core team members who work in conjunction with functional staff to develop, test, establish manufacturing processes and begin commercialization of the product. Accomplishing these tasks in this phase involves skill sets which are tacitly based, however implementation of these tasks also involves direction from explicitly documented project plans, functional requirements, and specifications.
Phase 5 - Rollout	approx. 30 % tacit, 70 % explicit	Main activities of this phase are mass manufacturing of the product and establishing sales and support plans. They occur mainly through established and explicitly documented manufacturing processes, although a component of tacit based knowledge still applies in carrying out manufacturing routines and processes.

Plotting the results of our findings for explicit/tacit knowledge use at Comm-Co:

Proposition 1b: Verifying the use of contextual versus technical tacit knowledge at each phase in the NPD process of Comm-Co.

Phase	Contextual versus Technical Tacit knowledge	Explanation of Breakdown
Phase 1 - Pre-concept	70 % technical, 30 % contextual	Comm-Co encourages idea generation from all areas of the company. In general new product ideas have come largely from the engineering discipline where a high component of technical tacit knowledge is used in the development of the idea. The contextual tacit component is needed as a result of the project approval committee analyzing each idea as to its strategic fit and business opportunity. The committee is comprised of senior people in the area of R& D, sales, marketing, finance, and spending who evaluate the idea based on their area of tacit expertise.
Phase 2 - Concept	30 % technical, 70 % contextual	Although new product ideas are predominantly technology driven at this company, their NPD methodology places strong importance on assessing the concept based on its business potential. Strong components of this contextual tacit based analysis are assessing the strategic fit, evaluating the market opportunity and assessing the preliminary cost and time of full scale product development activities. There is also a smaller component of technical tacit based analysis of the technology idea at a high level.
Phase 3 - Analysis	50 % technical, 50 % contextual	The cross functional core team is present in the analysis phase to validate the assumptions in the evaluation report brought forth by the concept team in the previous phase. Much focus is placed on the technical analysis and also a thorough business analysis. Also detailed at this phase are the product definition, the technical approach and the project plan. Many of the skill sets required for these activities are both technical and contextual in nature. Technical tacit knowledge is required in the development of the technical approach and contextual tacit is required to develop the business analysis.

Phase 4 - Implementation	70 % technical, 30 % contextual	This phase involves the Implementation of the project plan though core team members who work in conjunction with functional staff to develop, test, establish manufacturing processes and begin commercialization of the product. Many of the skill sets required for these activities are technical in nature and therefore come predominantly from a technical tacit knowledge base. Some contextual tacit knowledge is required to begin marketing activities required for product commercialization.
Phase 5 - Rollout	40 % technical, 60 % contextual	Main activities in this phase are the mass manufacturing of the product and establishing sales and support plans. Many of the skill sets required for these activities are both technical and contextual in nature. Technical tacit knowledge is required in the manufacturing process and contextual tacit is required to accomplishing the marketing and sales tasks required for product commercialization.

Plotting the results of our findings for contextual/technical tacit knowledge use at Comm-Co.

Proposition no. 1 is not validated by the data collected from Comm-Co. The proposition states that there is a strong presence of contextual tacit in the beginning and end phases. This argument was validated in all phases except within phase 1 and 2 of NPD where more technical tacit knowledge was used.

Exploratory Question 1 - Comm-Co

This question explores when, by whom and how the transfer and transformation of tacit knowledge occur in the NPD processes of Comm-Co.

Phase 1 - Pre-concept

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

Historically, new product ideas within Comm-Co have come from teams rather than one individual. Externalization and amplification of tacit knowledge are important inputs to the objectives of this phase, much of the new product idea generation process is tacit knowledge based. For example, one of Comm-Co's newest products has come as a result of joint work between some Comm-Co's more senior engineers and NRC researchers.

2) Who - The composition of the core and the extended team members of this phase:

- ▶ Individuals involved in the generation of the new product idea.
- ▶ Project Approval Committee (PAC) - approximately 5 senior people in the areas of R& D, sales, marketing, finance and spending accept or reject the new product idea.

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each stage:

- ▶ Externalization tool used - Many new product ideas within Comm-Co are delivered initially to the Project Approval Committee in prototype form. Recall that in the literature, prototyping has been described as one method of externalizing tacit knowledge.
- ▶ Co-located - Many of the player responsible for generating new ideas were co-located.
- ▶ Communication process - Much of the process of generating new ideas was done through frequent and informal face to face interaction.

Phase 2 -

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

Tacit knowledge externalization and amplification are highly important to the objectives of this phase. The mandate of the Concept Team is to expand the initial product idea of phase 1 by creating a high level analysis of the idea and then communicating or transferring this knowledge to the core team in the next phase. Some explicit knowledge, market research, is also amplified in this process.

This information is also transferred explicitly to the core team.

2) Who - The composition of the core and the extended team members of this phase:

- ▶ Concept team - approx. 2 to 3 people marketing and R & D related.
- ▶ Project Approval Committee (PAC).

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each phase:

- ▶ Externalization tool used - Comm-Co has individuals in the Concept Team that are referred to as abstractionists. Abstractionists are described by Comm-Co as individuals who can share ideas put ideas together quickly. These people are also described as being able to communicate the high level idea clearly so that others from different levels and from different disciplines within the core team can comprehend them. In summary, these people are able to externalized tacit knowledge quite easily.
- ▶ Co-located - No information on this.
- ▶ Communication process - Much of the process of analyzing the initial product concept by this team typically has been done through frequent and informal face to face interaction.

Phase 3 - Analysis

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

Tacit knowledge externalization and amplification are very important to the objectives of this phase. The core team validates more rigorously the assumptions put forth by the Concept Team in the analysis phase.

The effective externalization of tacit knowledge becomes important at this phase because core team members are responsible for transferring product knowledge to extended functional teams. This information is also transferred explicitly to the functional teams.

2) Who - The composition of the core and the extended team members of this stage:

- ▶ Core team consists of 7 to 8 people in the following areas: Core Team leader, Project Manager, Engineering, PLM, Marketing, Sales, Product Supply
- ▶ PAC

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each phase:

- ▶ Externalization tools used - Use case maps is one method that Comm-Co used to facilitate the externalization of tacit knowledge in this phase. The process of document writing was also sighted as another method in exercising and externalizing tacit knowledge. One interviewee commented that the process of writing forces individuals to communicate clearly the tacit knowledge found in one's head.
- ▶ Co-located - Many of the core team players are co-located.
- ▶ Communication process - mostly face to face interaction. The core project team members meet frequently in the initial weeks of this phase (twice a week) and then less frequently for the remaining duration (weekly) once the project plan and definitions have become more developed.

Phase 4 - Implementation

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this stage:

Tacit knowledge externalization and amplification are important to the objectives of this phase, however less important than at previous phases. The main objective of the implementation phase is to build the new product through a defined project plan. In the development phase of a new product, work is typically divided up into different components and developed separately. Some externalizing and amplifying is done to integrate these different sections of the product.

2) Who - The composition of the core and the extended team members of this phase:

- ▶ Core Team - same as above
- ▶ Support from the following Functional teams: Design (hardware and software), Testing and Verification, Manufacturing
- ▶ PAC

3) Mechanisms - Mechanisms used to achieved the transformation and transfer of tacit knowledge at each phase:

- ▶ Externalization Tools used - CAD (computer assisted designs) and Case Maps are relied on extensively in this phase as methods of externalizing and recording tacit knowledge between development groups and development and testing and verification groups. Brainstorming was also sighted as an externalization method which proved helpful in developing a user interface design for one new product.
- ▶ Co-located - Development and Testing and Verification groups are co-located. Cubicle work stations are used.
- ▶ Communication process - Most of the interaction within these small technical groups is conducted informally, frequently and face to face. (1) The core product team members meet weekly. This meeting does not act as a knowledge building meeting but more as a status meeting run by the project manager. (2) In development, lab meetings are used as an adjunct to ongoing face to face interaction. These sessions act as feedback sessions and occur 1 to 2 times each week. Some one presents their area of work and others will provide feedback. (3) Sounding board meetings are used also to integrate different sections of the first development version. Typically these meetings take place once a month.

Phase 5 - Rollout

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

Tacit knowledge externalization and amplification are not as important to this phase as in previous phases. Manufacturing occurs through plans previously outlined in former phases and now being carried out. However, there are some new manufacturing processes that will be required for the manufacturing of the new product. Tacit input is required to develop these new processes.

<p>2) Who - The composition of the core and the extended team members of this phase:</p> <ul style="list-style-type: none"> ▶ Core team - same as above ▶ Support from the following functional teams: Manufacturing, Sales, and Support ▶ PAC
<p>3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each phase:</p> <ul style="list-style-type: none"> ▶ Externalization methods used in this phase are mostly accomplished through the use of computer aided diagrams. ▶ Co-located - Manufacturing employees for NPD are co-located. ▶ Communication process - Most of the communication is accomplished informally and face to face through the co-location, as indicated above.

Exploratory Question 2 - Comm-Co

This question explores issues that might account for why the tacit knowledge transfer and transformation process might not go the way it should, and also the types of tacit knowledge that are typically not transferred into the NPD process but are argued to be important.

Description of Problem	How this Problem hinders the transfer and transformation of tacit knowledge - the knowledge building process
<p>1) Structure of Meetings - the structure of meetings refers to how meetings are conducted, that is, the number of people at each meeting, the length of time of the meeting, whether the meeting is run with clear objectives or an agenda and if the meeting is conducted in a manner that facilitates or hinders the knowledge transfer process between members of the meeting.</p> <p>Comments were made that meetings are at times conducted too loosely. Tacit knowledge transfer and retention can be difficult if the objective issue is not clearly stated. See Chapter Two, Numata and Taura (1998).</p>	<p>1) Meetings are often a source of information overload. If the objectives of a meeting are not clearly outlined, knowledge transfer and retention can be hindered, however, if the objectives of the meeting are clearly outlined it provides a point of focus with respect to knowledge that should be retained and stored and used tacitly later on.</p>

<p>2) Most predominant problem sighted at Comm-Co has to do with the need for the integration of more customer feedback (tacit knowledge transfer) at all phases in the NPD process, several comments made in this area:</p> <ul style="list-style-type: none"> ▶ The need for a customer voice to be inside R & D activities. ▶ Ideally to have the customer sit in with the NPD team. ▶ A greater need exists to understand first hand in R & D what the customer needs. ▶ Client usability needs to be examined more thoroughly at each phase. ▶ We are beginning to get the customer in earlier in the NPD process but this has to occur more frequently. 	<p>2) Client input (tacit knowledge transfer) at each phases will increase successful NPD outcome.</p>
<p>3) The greater need/opportunities for people to interact either socially or formally to present to one another what they do.</p>	<p>3) Greater interaction either socially or formally encourages the knowledge sharing process (Von Krogh, 1998). A strong knowledge sharing environment encourages the tacit externalization and amplification process.</p>
<p>4) In general some knowledge hoarding at Comm-Co does exist, more so in the engineering disciplines.</p>	<p>4) Knowledge hoarding makes the task of tacit knowledge transfer and transformation very difficult, and it can be detrimental to the outcome of the development process.</p>

NPD Phase	Description of Problem	How this Problem hinders the transfer and transformation of tacit knowledge - the knowledge building process
Phase1 - Pre-Concept		
Phase 2 - Concept		

Phase 3 - Analysis	<p>1) User Needs - Several comments were made concerning the need for more market research on the user need. This includes tacit forms of feedback from the user.</p> <p>2) Several comments were made concerning communication problems between core team members. Wrong assumptions occur between team members from different disciplines. This often means incorrect development of high level definitions.</p>	<p>1) The wrong information becomes amplified in the design and development process.</p> <p>2) Difficulties in externalizing tacit knowledge between people from different disciplines often exists. When an idea is being presented it is common for others to develop erroneous assumptions around what is being said. One comment was made that this problem may be solved in part though training on listening skills.</p>
Stage 4 - Implementation		
Stage 5 - Rollout		
Phase 6 - Ongoing Sales and Support	<p>1) Several comments were made concerning the ramifications that poor documentation in NPD can have on continued product development.</p>	<p>1) Poor documentation in the NPD process makes the tacit amplification process in the continued development cycle difficult.</p>

Exploratory Question 3 - Comm-Co

This question explores factors that enable the transfer and transformation of tacit knowledge.

Comm-Co has suggested several factors:

- ▶ Developing a culture of employees that understand and focus on the concepts of knowledge hoarding and knowledge sharing.
- ▶ Flat organizations make knowledge sharing and building easier. Comm-Co is a relatively flat organization, they believe that this type of organizational structure promotes free flowing communication (hierarchy implicitly assume that those at the higher levels of the organization hierarchy have the greatest knowledge).
- ▶ Co-location - co location has been sighted as being as the most important factor within Comm-Co to achieving the externalization and amplification of tacit knowledge. Frequent and informal face to face interaction provide the greatest exposure to possibilities of externalizing and amplifying tacit knowledge between team members on an ongoing basis.

Comm-Co uses co-located cubicles where conversations can be heard more readily than co-located offices. They believe that this type of set up often negates the need for formal meetings. Also if possible co-location of divisions is suggested. At Comm-Co design, manufacturing, and marketing heads are co-located.

- ▶ Providing a place and time where knowledge can be shared and transferred; Quarterly meetings, weekly social evenings and demonstrations days. Also freeing up time, that is placing less restrictions on time to market will also help to foster an environment where tacit externalization and amplification will be achieved with greater ease.
- ▶ Ensuring the continuity of knowledge from phase to stage will help in ensure that the correct knowledge is amplified. Comm-Co believes that the use of cross discipline core teams provides continuity of knowledge.
- ▶ Providing a good bonus structure to ensure the externalization and amplification of tacit knowledge in the knowledge building process. Comm-Co recently changed from a compensation bonus system tied to company performance to a bonus system based on specific R & D objectives. These compensation bonuses provide an incentive to share and transfer knowledge necessary for timely development of specific R & D projects.
- ▶ Management Training - For those managers who will be leading and enabling the knowledge building process at each phase management training is recommended by Comm-Co to provide greater knowledge on how team building meetings may be facilitated.
- ▶ Creating Ownership of NPD Tasks - When NPD members are given specific ownership and made accountable for certain tasks the externalization and amplification of tacit knowledge in the knowledge building process is facilitated. Giving accountability of certain tasks to people does not in itself ensure communication, however it gives them the responsibility to ensure that they get what they need. This of course includes ensuring the transfer of certain knowledge needs from others to them.
- ▶ Create teams that are not too large. Smaller teams have the opportunity of communicating more frequently with each other. Recommended size of 20 people or less.
- ▶ If teams of a larger size exist, Comm-Co recommends the use of formal processes to ensure the proper transfer of knowledge, explicit and tacit. With out this formal process no assurance is provided that knowledge is transferred from and to the correct players in the NPD process.
- ▶ The use of team facilitators to help with emotional obstacles that block the sharing and transferring of tacit knowledge in the knowledge building process.
- ▶ Use of brainstorming processes to facilitate the externalization of tacit knowledge. For example brainstorming was used to develop an array of business solutions to customer problems.
- ▶ Fostering trust within groups enables the knowledge sharing and building process. Comm-Co uses team building exercises to promote group trust.
- ▶ Rewarding behaviors to those that disseminate and facilitate the transfer of tacit knowledge.

Tel-Co Analysis
Responses to Exploration and Proposition Investigation

Tel-Co
NPD Process Overview

Verifying Hypothesis No. 1 - Tel-Co

Verifying Proposition 1a: verifying the use of tacit versus explicit knowledge at each phase in the NPD process of Tel-Co.

Phase	Tacit Versus Explicit Knowledge	Explanation of Breakdown
Phase 1 - Idea Generation	approx. 70 % tacit, 30 % explicit	<p>New product ideas within Tel-Co are encouraged from different areas of the firm. They are derived on the basis of information pulled from various types of marketing analysis and are also pushed from different functional areas of the firm. Although tacit knowledge often plays a large part in the development of any new product idea, it plays a smaller role during the idea phase at Tel-Co. All new product ideas, regardless of where they have been derived, are often tempered by highly defined strategic and market goals explicitly outlined by the firm.</p> <p>The product concept is pulled together further at this phase by a few senior people from the area of marketing and engineering. This team, called the Opportunity Team, prepares a preliminary business case and outlines the high level over view of the product. The components of the analysis at this phase require the use of much tacit knowledge and skill acquired only through many years of work experience.</p>

Phase 2 - Opportunity	approx. 60 % tacit, 40 % explicit	<p>The Opportunity Team of the previous phase continue their analysis of the product concept during this phase. The goals of the analysis at this phase are to understand at a much greater depth the viability of the product concept and the extent of its business potential. Tacit knowledge is used to conduct the analysis but a good deal of explicit knowledge is also used to fill in factual gaps of the analysis brought forth from the previous phase. Identifying the current market segment, the competitive landscape and establishing high level technical and market requirements would all be necessary parts of the analysis conducted during this phase.</p>
Phase 3 - Definition	approx. 50 % tacit, 50% explicit	<p>Before an excessive amount of money is committed to continued product development a final assessment must be made on the ultimate profitability of the product and if it will make the best use of the company's time and manpower.</p> <p>During this phase the core team is formed. It is typically comprised of 7 - 8 members in the areas of development, product line management, customer support, quality assurance, manufacturing, marketing and finance.</p> <p>The business case assumptions, the requirements and the technical definition put forth by the previous team are confirmed and outlined in further detail by this team before a serious development commitment is made. The business case at this phase will identify and clearly outline the minimal viable product necessary to create a winning product, what is and what is not technically feasible, the associated risks with development and vital product features. These tasks require a combination of explicit and tacit knowledge.</p>

Phase 4 - Implementation	approx. 35 % tacit, 65 % explicit	<p>The objective of this phase are to develop the product based on explicitly outlined project plan details, technical specifications and market requirements outlined in the previous phase. Extended functional teams accomplish the development, testing and integration of the hardware and software components of the product. The customer continues to be engaged during this phase and feedback continues to be filtered back to the development process through the PLM and the Customer Support Prime.</p> <p>Also developed during this phase are the marketing and sales plans, customer support service plans, customer documentation and training manuals and the production and materials plan. Although a variety of tacit skill sets are used in the implementation of tasks geared towards the development of the product a large part of the development of this phase is also guided and influenced by explicitly outlined project details, specifications and requirements.</p>
Phase 5 - Deployment	approx. 30 % tacit, 70 % explicit	<p>The main objective of this phase is to complete acceptance testing of the product and to prepare for volume production. Other objectives of this phase are to implement the sales and the marketing plans, implement the support and service plans and deliver the training and product documentation. This phase is also largely driven by explicitly outlined plans, although some tacit knowledge is used in plan implementation.</p>

Phase 6 - Production	approx 20 % tacit, 80 % explicit	<p>The main activity of this phase is the volume production of the product. The core team involvement comes to an end during this phase. They prepare to hand off the product to another team who will be responsible for the continued improvement and support of the product until the product is retired. Much of the hand off is done through the transfer of explicit knowledge (documents), although both the Marketing and the PLM Prime may also transition from the core team to this team, transferring their own tacit product knowledge. During this phase the performance of the product also begins to be monitored and evaluated against the business case developed in previous phases. In summary, explicit knowledge plays a large role at this phase in the volume production of the product, in the hand off of the product knowledge to the next team, and in the monitoring of the product performance against the business case.</p>
----------------------	----------------------------------	---

Plotting the results of our findings for explicit/tacit knowledge use at Tel-Co:

Proposition 1b: Verifying the use of contextual versus technical tacit knowledge at each phase in the NPD process of Tel-Co.

Phase	Contextual versus Technical Tacit Knowledge	Explanation of Breakdown
Phase 1 - Idea Generation	approximately 65% contextual tacit and 35 % technical tacit	Although many new ideas for product development have come largely from the R & D side of the organization (technology business group, disruptive technology and various functional parts of the organization) the development of these ideas within these groups have been influenced strongly by the strategic vision and the marketing goals of the firm (guiding contextual tacit knowledge). The marketing vision of Tel-Co is explicitly and clearly laid out and appears to be constantly referred to through out the entire development cycle. Hence, contextual tacit plays a strong role in the new idea development process at Tel-Co.
Phase 2 - Opportunity	approximately 70 % contextual tacit and 35 % technical tacit	<p>Emphasis in this phase is placed on expanding the business case introduced in the previous phase. Some of the areas of the expanded business case analyze current and future market segments, the competitive landscape and establish high level technical and market product definitions. Specific focus is placed on how this product may be differentiated from other current and future competing products. The first contact with the lead customer is also usually initiated during this phase.</p> <p>The tacit knowledge needs of this phase tends to come predominantly through marketing, product line management and the customer, much of which is contextual tacit in base. Some tacit and explicit technical knowledge is also used in the technical feasibility analysis and high level technical product definition.</p>

Phase 3 - Definition	approximately 50 % contextual tacit and 50 % technical tacit	<p>During this phase the core team validates the assumptions and also expands on the business case analysis put forth by the Opportunity Team. The business case at this phase will identify and clearly outline the minimal viable product necessary to create a winning product, what is and what is not technically feasible, the associated risks with development, and vital product features.</p> <p>The tacit knowledge needs of this phase tends to come predominantly from development, marketing, product line management and also the customer, which are both contextual and technical tacit in base. Both types of tacit knowledge seem to be equally important to the goals of this phase.</p>
Phase 4 - Implementation	approximately 35 % contextual tacit and 65 % technical tacit	<p>The objective of this phase is to develop the product based on explicitly outlined project plan details and technical specifications and market requirements outlined in the previous phase.</p> <p>Extended functional groups accomplish the development, testing and integration of the hardware and software components of the product. The customer continues to be engaged during this phase and feedback continues to be filtered back to the development process through the PLM and the Customer Support Prime. Also developed during this phase are the marketing and sales plans, customer support service plans, customer documentation and training manuals and the production and materials plan</p> <p>A large variety of tacit skill sets are used in the implementation of tasks geared towards the development and commercialization of the product. Of those tasks outlined above, a larger percent is required from the technical tacit domain than the contextual tacit domain.</p>

Phase 5 - Deployment	approximately 50 % contextual tacit and 50 % technical tacit	<p>The main objective of this phase is to complete acceptance testing of the product and to prepare for volume production. Other objectives of this phase are to implement the sales and the marketing plans, implement the support and service plans and deliver the training and product documentation. This phase is largely driven by explicitly outlined plans, although some tacit knowledge is used in implementing the plans.</p> <p>A large variety of tacit skill sets are used in the implementation of tasks geared towards the testing and commercialization of the product. Of those outlined above both contextual and technical tacit are equally important to fulfilling the objectives of this phase.</p>
Phase 6 - Production	approximately 65 % contextual tacit and 35 % technical tacit.	<p>The main activity of this phase is the volume production of the product. The core team involvement comes to an end during this phase. They prepare to hand off the product to another team who will be responsible for the continued improvement and support of the product until the product is retired. Much of the hand off is done through the transfer of explicit knowledge (documents), although both the Marketing and the PLM Prime may also transition from the core development team to this team transferring their own tacit product knowledge.</p> <p>Tacit skill is used to accomplish the volume production of the product and the transfer of the product to the next team who support and sustain the product through its remaining life. Both contextual and technical tacit is used in this phase. As production comes to an end more contextual tacit is used to transfer the project to the next team and to develop the marketing and sales activities to sustain the life of the product.</p>

Plotting the results of our findings for contextual/technical tacit knowledge use at Tel-Co.

Proposition no. 1 is for the most part validated by the data collected from Tel-Co. The proposition states that there is a need more for contextual tacit knowledge at the beginning and end phases of the development process and a need more for technical tacit at the mid phases of the development process. Contextual and technical tacit knowledge use fits this pattern of use as outlined by proposition 1.

Exploratory Question 1 - Tel-Co

This question explores when, by whom and how the transfer and transformation of tacit knowledge occur in the NPD processes of Comm-Co.

Phase 1 and 2 - The Idea Generation and Opportunity

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

New product ideas tend to come from the development side of the organization within Tel-Co. Although development driven, ideas appear to be aligned with or at minimum strongly tempered by the marketing and strategic goals of the firm.

After the product concept is introduced, it is pulled together further in phase 1 and 2 by a few highly senior people in the area of marketing and engineering. The knowledge building/innovation process is important to these phases, because the concept needs to be further defined before serious development commitments are made.

2) Who - The senders and the recipients of knowledge transfer and transformation.

- ▶ Sender - Product Ideas are fueled through the following sources: senior person in charge of all investments, Technology Business Group, Disruptive Technology Group and from the functional divisions of the organization.
- ▶ Recipient - Opportunity Team: 2- 3 senior individuals in the area of marketing and engineering.
- ▶ Sender - Lead Customer

The product concept is transferred to the Opportunity Team who build on the idea by examining its business potential and defining further the product concept based on an initial competitive market analysis. In phase two, this same team expands on the concept further by analyzing and outlining in greater detail the current and future market segments and competition, and by providing a more solid definition of the product vis a vis its market and technical requirements. This information is then transferred back to the Portfolio Management team who decide if the product idea is worthy of further investment and time. The PMT team may amplify the enlarged concept by providing feedback or direction.

The first contact with the lead customer is also usually initiated during phase two. The lead customer may also amplify the product by providing feedback on customer requirements.

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each stage:

- a. Support Structures: a1) Co-location - The Opportunity Team members are usually co-located for the duration of the idea and the Opportunity Phases. Because of the co-location of the team much of the knowledge sharing and transfer occurs face to face and occurs frequently, a2) Meetings - frequent face to face contact is achieved through many informal meeting between the members of the Opportunity Team.
- b. Communication Mechanisms: b1) Externalization tool - much of the externalization process in this phase was accomplished through high level drawings of the potential system.

Phase 3 - Definition

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

Before continued development occurs the assumptions and analysis outlined by the Opportunity Team are validated and expanded by the core team. The knowledge building process is important to this phase because the ideas outlined in the previous phases now need to be validated and expanded before more serious development occurs.

2) Who - The senders and the recipients of knowledge transfer and transformation:

- ▶ Senders - Opportunity Team
- ▶ Recipients - core team: typically comprised of 7 - 8 members who drive the development process forward and who also act as the primary contact and manage extended functional development activities necessary for the continued design, development, manufacturing and commercialization of the product. The IPT members consist of the Project Leader, the Development Prime, the Product Line Management Prime, the Quality and Assurance Prime, the Customer Support Prime, the Manufacturing Prime, the Marketing Prime and the Finance Prime.

The expanded product concept and business case analysis of the Opportunity Team is transferred to the core team. In this phase this group validates the assumptions put forth by the Opportunity Team and expands the product concept further to include a more solid and well defined technical and market definition of the product, a fuller marketing and risk analysis, and also outlines the minimum viable product necessary to create what is believed to be a winning product.

3) Mechanisms - Mechanisms used to achieve the transformation and transfer of tacit knowledge at each stage:

- a. Support structure: a1) Co-location - The core team are co-located, except the Marketing Prime and the Finance Prime. Cubicles and open space provide a feeling of openness and provide easy access to knowledge sharing and information. Because of the co-location of the team much of the knowledge sharing and transfer occurs face to face and occurs frequently, a2) Meetings - IPT meetings occur weekly. During the initial months of the inception of the team they occur biweekly. The meetings are two to three hours in length and consist of the core team members only. The meetings are run in the open so that other extended functional members of the development or design teams can hear what the issues are, and what is being discussed.
- b. Communication Mechanisms: b1) Externalization Tools - System Drawings, story telling and analogies are often used to communicate the product and cultural norms and attitudes needed to develop a new product.

Phase 4 - Implementation Phase

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

In the implementation phase the product is designed and developed based on the alpha, beta philosophy of rapid customer engagement. That is to say, at incremental development steps customer feedback is initiated and fed back into the development process. The design, development and testing and verification of the product software and hardware components are accomplished through extended functional teams managed by the members of the core team.

The innovation process becomes less important at this phase than in previous phases where the technical specifications and the ASIC's of the hardware and software are yet to be designed. However, some form of knowledge building and innovation does take place in this phase as the product design takes on more product features and is stabilize though incremental development steps.

2) Who - The senders and the recipients of tacit knowledge transfer and transformation

- ▶ Sender - core team
- ▶ Recipients - Extended Design Team
- ▶ Recipients - Extended Development Team
- ▶ Recipients - Extended Product Line Management Team
- ▶ Recipients - Extended Quality and Assurance Team

The product definition is transferred from the core team to several design teams who outline with more detail the specifications and the ASICS needed to build some of components of the product. These separate components are built and then integrated. The integrated product is transferred from the development team to the quality and assurance who will test for product stability. The process of stabilizing the product becomes an iterative process between development and Q and A as the product becomes more and more robust.

3) Mechanisms - Mechanisms used to achieved the transfer and transformation of tacit knowledge at each stage:

- a. Support Structure: a1) Co-location - Members within the same functional group are co-located. The different functional design and development groups are not necessarily co-located. Some of the ASIC development was accomplished by third party vendors. Most of the work accomplished within each functional group is accomplished informally and face to face due to the co-location of group members. Meetings between groups are established to ensure integration of the product components. Details about the product integration meetings was not obtained in this research.
- b. Communication Mechanisms: b1) Externalization tools - Extensive use of system diagrams and flow charts to describe the nature of each product part, CAD CAM was used.
- c. Because of the nature of the quality assurance role, that is, verifying and logging product problems, the interaction between development and Q and A can at times be difficult for many companies. Tel-Co is cognizant of the tensions that sometimes exist between these two groups and there fore takes specific steps to support and encourage good relations. For example, although the two groups are not co-located management of both groups recommends as much face to face interaction as possible when a problem is logged and needs to be fixed. Also, effort is made by both groups to educate the other group as to what they do. Presentations and question and answer periods are conducted.

Phase 5 and 6 - Deployment and Production

1) Degree - The degree that the tacit knowledge transfer and transformation process is important to the objectives of this phase:

The main objectives of these phases are to complete acceptance testing of the of the product, prepare and implement volume production and hand off the product knowledge and information to another team outside the core team who will be responsible for the continued improvement and support of the product until the product is retired.

The innovation and knowledge building process are much less important to these phases than in previous. Hence tacit knowledge transfer and transformation are also less important during these phases. However, some form of knowledge building and innovation does take place during phase five when new manufacturing processes are developed to accommodate the volume production of the new product.

2) Who - The senders and the recipients of knowledge transfer and transformation

- ▶ Senders - Development Engineers
- ▶ Senders - Manufacturing Prime
- ▶ Recipients - Manufacturing Engineers
- ▶ Recipients - Manufacturing Quality and Assurance
- ▶ Recipients - Retirement product team
- ▶ Recipients - Account Team

The development engineers communicate and transfer product design information both explicitly and tacitly to manufacturing operations. The account team transfers information to the PLM Prime concerning the possible number of accounts that are interested in purchasing the product upon general availability before volume production takes place. The PLM Prime transforms this information into a production forecast document that is then transferred both tacitly and explicitly to the Manufacturing Prime. The Manufacturing Prime transfers this knowledge explicitly to the Manufacturing Engineer who forecasts the amount of materials to be ordered for volume production. The Quality and Assurance Manufacturing prime will sit in occasionally on the core team meetings to ensure that information and knowledge vis a vis product, quality and time to market standards will be maintained during manufacturing and volume production.

3) Mechanisms - Mechanisms used to achieved the transformation and transfer of tacit knowledge at each phase:

- a. Support Structure: a1) Co-location - Manufacturing and Design are not co-located, although development engineers do spend 2 - 4 days with manufacturing engineers face to face, attempting to transfer both tacit and explicit product knowledge necessary for product manufacturing.
- b. Communication Mechanisms: b1) Externalization Tools - Demonstration and system diagrams

Exploratory Question 2 - Tel-Co

This question explores issues that might account for why the tacit knowledge transfer and transformation process might not go the way it should, and also the types of tacit knowledge that are typically not transferred into the NPD process but are argued to be important.

Description of Problem	How this Problem hinders the Transfer and Transformation of Tacit Knowledge - The Knowledge Building Process
1) The danger of cross functional core teams - Because core team members are from different disciplines, knowledge can often be misinterpreted. This occurs most when the product is being defined with greater detail in phase two and three of the NPD process.	Knowledge can easily be misinterpreted between members of a cross functional team. Support or mechanisms must be put into place to check assumptions and ensure that the correct knowledge is being amplified or transferred.
2) Members are at times communicating too often through e-mail. Knowledge break down can occur as a result of using e-mail more frequently than face to face communication during high periods of tacit knowledge transfer and transformation.	Information can be easily misinterpreted in an e-mail and hence the wrong knowledge can be amplified.
3) Need for more avenues in which to share knowledge between projects (lessons from each new product development effort) and to share knowledge between individuals within the same position or function. I.e. Lack of knowledge sharing opportunities exist between development primes.	More avenues for knowledge sharing ultimately facilitates the knowledge building process that occurs in NPD initiatives.
4) More effort to train designers that will support the development of specific technologies long term. Tacit knowledge transfer from specific domains.	Will facilitate the knowledge building process long term.
5) The tacit knowledge externalization and communication process can be difficult when cross functional project team members differ in age, sex and culture/language.	The existence of differing age groups, sexes and cultures within a team makes the externalization and amplification process difficult. There are techniques that can be used that can help to minimize the negative effects that these differences have on the knowledge building process.
6) Weekly meetings for core team are at times too long and lack focus. Beyond two hours is too long.	Meetings are often a source of information overload. If there is a lack of focus or the objectives of the meeting are not clearly outlined information retention/tacit knowledge retention is hindered.

NPD Phase	Description of Problem	How this Problem hinders the Transformation and Transfer of Tacit Knowledge - The Knowledge Building Process
Phase 1 - Idea		
Phase 2 - Opportunity		
Phase 3 - Definition	<p>1) When a new team is first formed, trust between core members may exist. Lack of trust can hinder good communication. Trust building events and exercises are used by Tel-Co T to help foster the trust that is needed to have the core team IPT communicating well and moving forward in a positive direction.</p> <p>2) The danger of core teams - Because core team members are from different disciplines information can often be misinterpreted. This occurs most when the product is being defined with greater detail in phase two and three of the NPD process.</p> <p>3) The Marketing Prime is not co-located with the rest of the cross functional core team, he/she will not be privy to informal conversations that take place between other team members who are co-located.</p>	<p>Lack of trust between team members hinders tacit knowledge sharing and transfer.</p> <p>Information can easily be misinterpreted between members of a cross functional team. Proper leadership support or mechanisms must be put into place to continually check assumptions and ensure that the correct information is being amplified or transferred between NPD teams.</p> <p>Co-location facilitates, frequent, informal face to face interaction and therefore also supports the transfer and transformation of tacit knowledge.</p>

Phase 4 - Implementation	<p>1- Insufficient new technology training (tacit knowledge transfer) is provided/transferred from development to manufacturing. Although manufacturing sits with and works closely with development for a period of approximately 4 days to transfer new product knowledge, that period is too short to transfer adequate product knowledge for manufacturing purposes.</p> <p>2) Need for live documents to facilitate the task of externalization in the design and development process.</p> <p>3) A representative from Q and A is not a recommended part of the core team.</p>	<p>Manufacturing mistakes are costly and so a period of 1 month is recommended to ensure that adequate product knowledge is transferred.</p> <p>It is very important for Q and A to be a part of the cross functional core team so that they can understand (tacitly) the requirements that are coming in from the customer and make sure that testing is in line with what the customer is expecting.</p>
Phase 5 - Deployment	<p>1-Development and Manufacturing are not co-located. Prototype problem solving between the two areas can be difficult because of the lack of face to face interaction. Prototypes must be physically transferred between these two areas. Shipping problems have often caused delays in the prototype design and development.</p> <p>2) Tel-Co's NPD model needs to create more check points at areas in the process where quality is verified. Faster time to market is important but not at the expense of product quality.</p>	<p>Physical separation between the area of development and manufacturing makes the knowledge building or problem solving process (less tacit knowledge transfer) difficult and more time consuming.</p> <p>Check points will ensure that certain aspects of product verification occurs before the product reaches the customer.</p>

Phase 6 - Production	<p>1- The product knowledge “hand off” or transfer process from the core team is not usually conducted well. In general the life cycle team does not acquire an adequate level of new product knowledge. There is no clear and defined process that outlines how the product knowledge should be transferred from the core team</p> <p>The lack of a defined knowledge transfer process also exists with respect to the transfer of product marketing knowledge from the Marketing prime on the NPD core team to the marketing function on the continuous product development team.</p>	<p>This lack of knowledge will probably affect the service that the product life cycle team provides to the customer. They may be unable to answer customer questions. Also, without a clear defined process for transferring the tacit knowledge of the core team, valuable new product knowledge will disappear.</p>
----------------------	---	--

Exploratory Question 3 - Tel-Co

This question explores factors that enable the transfer and transformation of tacit knowledge.

Tel-Co has suggested several factors:

- ▶ Optimistic and positive project leadership. Many obstacles arise during the development of a new product. Optimistic and positive support alleviates project stress and frees up space for communication and tacit knowledge sharing and transfer.
- ▶ The use of social events and team building events to create team cohesiveness and strength. Team cohesiveness and strength facilitates the communication and sharing process.
- ▶ Creating team accountability or ownership. Team accountability or ownership facilitates ownership of individual development tasks. This in turn encourages communication and transfer of explicit and tacit knowledge to accomplish end tasks.
- ▶ Co-location of core project members. The co-location of team members in cubicles facilitates informal, frequent and face to face communication, which in turn facilitates the transformation and transfer of tacit knowledge.
- ▶ Characteristics of a meeting that facilitates that transfer of knowledge - meeting facilitator to keep the meeting on track, maintain focus throughout, clear agenda, non personal interaction and good conflict resolution in meetings.
- ▶ Courses provided on teaming and conflict resolution to help facilitate communication and the transfer and transformation of tacit knowledge.
- ▶ The existence of the same core project team facilitates the transfer and transformation of tacit knowledge because the continuity of knowledge is maintained from the beginning to

the end of the NPD process.

- ▶ The cross functional representation on the core project team facilitates the transfer of tacit knowledge to the extended functional teams.
- ▶ Lunch and learns or knowledge sharing forums provide an avenue to share and transfer technical know-how. Each lunch and learn session provides a presentation on a specific technology.
- ▶ Incentive systems - for example profit sharing and team rewards provide a motivation to share and transfer knowledge during the development of the new product.
- ▶ Mentoring - language and team mentoring encourage knowledge sharing and transfer.
- ▶ Providing rewards for product development champions. Product development champions typically champion a product development initiative and encourage sharing and the transfer of knowledge.