THE IMPACT OF THE USE OF INTERNET-BASED TECHNOLOGIES ON NEW PRODUCT DEVELOPMENT PERFORMANCE

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ABSTRACT

Faced with the rapidly changing environment and the necessity to effectively manage the collaborative nature of product development, numerous firms invest in Internet-based technologies (IBT) to support their innovation activity. However, despite the vast theoretical and case-study-based research in the literature regarding the alleged role of Internet-based technologies in new product development (NPD), there is no systematic large-scale empirical evidence which would confirm that the use of Internet-based technologies leads to improvement of NPD performance.

In order to address this issue, this thesis examined the impact of the Internet-based technology use on NPD performance. First, a novel conceptualization and definition of IBT use construct was proposed. Internet-based technology use in NPD project was defined as the extent to which the project team deploys Internet-based technologies to support NPD project activities and processes. It was conceptualized as a four dimensional construct, each of the dimensions reflecting a domain of application of the technology.

Next, based on an extensive review of the literature a research model was developed proposing that IBT use has a positive impact on NPD performance. It was further hypothesized that this impact is indirect and takes place through improvement of communication quality, effectiveness of team learning and team integration.

In order to test the model, data was collected by means of a questionnaire. The sampling frame comprised of managers of product development projects from Canadian and American manufacturing companies operating in high-tech industries. The questionnaire was completed by 278 respondents. Based on the collected data, the theoretical framework was evaluated using structural equation modeling approach.

IBT use was found to be significant contributor to all three dimensions of NPD performance: product quality, time-to-market and development cost. The hypothesized indirect nature of this relationship was also confirmed. The total impact of IBT use on NPD performance was found to be significantly higher for projects devoted to development of highly innovative products and for projects executed by global teams.

This thesis contributed to the theory by synthesizing and extending previously disparate studies to develop a unified model of Internet-based technology use in NPD and by testing this model empirically.

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CHAPTER 1

INTRODUCTION

During the past 25 years new product development (NPD) has increasingly been recognized as a critical factor in securing long-term survival, competitiveness, growth and sustained commercial success of firms (Craig and Hart, 1992; Brown and Eisenhardt, 1995; Deschamps and Nayak, 1995; Cooper, 1996; Jenkins *et al.*, 1997; Biemans, 2003). As a result, the necessity to innovate is not only shared by companies committed to a technological leadership strategy, but also by all companies simply trying to maintain their market position or secure their survival. Researchers and practitioners view the development of new products as "the focal point of industrial competition" (Clark and Fujimoto, 1991) and argue that: "the future of all firms depends upon their ability to continuously introduce quality new products that meet their customers' needs and at the same time have steadily decreasing development cycle-times" (Jenkins *et al.*, 1997).

The increased recognition of the critical importance of NPD for a company's survival and success has resulted in a vast body of conceptual and empirical research investigating, among other things, the nature of NPD process in terms of its stages and activities involved at each stage (Booz-Allen and Hamilton, 1968; Rothwell, 1994; Hart and Baker, 1994; Song and Montoya-Weiss, 1998; Pillai and Rao, 2000; Ozer, 2003), the measurement of NPD performance (Clark and Fujimoto, 1991; Emmanuelides, 1993; Neely *et al.*, 1995; Doz, 1996) and factors that contribute to NPD success (Cooper, 1979a,b, 1980a,b, 1983, 1990; Cooper and Kleinschmidt, 1987, 1993, 1994, 1996; Barczak, 1995; Calantone *et al.*, 1997; Dwyer and Mellor, 1991; Griffin, 1997; Parry and Song, 1994; Ernst, 2002). However, despite these numerous studies and recommendations addressing new product development, the failure rates of new product introductions are considered very high and companies in many industries struggle with new products that do not meet quality or cost objectives, are late to market, or are not meeting customers' expectations (Pillai and Rao, 2000). Unsatisfactory rates of NPD success are often attributed by researchers to the fact that the needs of product development are changing rapidly due to the changes in the environment, but have not yet been fully addressed by the academic research or practitioners (Nonaka and Takeuchi, 1995; Johannessen *et al.*, 1999; Pillai and Rao, 2000).

Increased competition, growing complexity of technologies and new products, more demanding customers with rapidly changing requirements, and faster product cycles are among the most significant trends in NPD environment which took place over the past two decades and had created new demands and challenges for firms involved in NPD activities (Cooper, 1994; Rothwell, 1994; Pillai and Rao, 2000; Kerssens-van Drongelen and Cook, 1997; Kerssens-van Drongelen and Bilderbeek, 1999; Kerssens-van Drongelen *et al.*, 2000; Haque and Pawar, 2003). Investigation of these changes has led some authors (Chiaromonte, 2002; Liyanage *et al.*, 1999; Rothwell, 1994) to suggest a concept of the evolution of NPD into the 'fourth' or even the 'fifth generation'. In the fifth generation NPD context, a significant increase in the dispersion of knowledge involved in the NPD process is viewed as one of the main challenges facing companies undertaking NPD efforts (Liyanage *et al.*, 1999; Rothwell, 1994).

In order to successfully develop a new product, the fusion of multiple technological disciplines is often required (Kodama, 1992), but it is usually impossible for a single R&D department or even a whole company on its own to entirely develop all the knowledge and information critical for innovation (Chiesa and Manzini, 1997; Bakker *et al.*, 2006). Therefore, numerous researchers and practitioners argue that firms need to view NPD as a joint effort and build cooperative structures consisting not only of different internal organizational units with diverse expertise relevant for the given NPD project, but often including also different external partners, such as customers, suppliers, manufacturers of complementary products, universities and even competitors (Brown and Eisenhardt, 1995; Chiesa and Manzini, 1997; Chiaromonte, 2002; Becker and Zirpoli, 2003; Biemans, 2003).

However, creating effective collaborative structures in which resources, knowledge, and information would circulate rapidly and at low cost is very difficult (Chiesa and Manzini, 1997). Among many other challenges, the assignment of parts of the NPD process to individuals from different departments or from external organizations raises the need for significant effort to coordinate the work of these numerous entities participating in the NPD process. Also, involvement of numerous, often dispersed owners of knowledge calls for more intensive efforts directed at achieving high quality communication and effective team learning processes. As Becker and Zirpoli (2003) pointed out "from the management perspective, the central challenge in the organization of the NPD process is how to integrate and co-ordinate the specialist knowledge and competencies of the participants in the NPD process". Different theories, including cooperation theory (Deutsch, 1949; Tjosvold, 1986, 1988), transaction cost theory (Thompson, 1967; Van de Ven *et al.*, 1976), information-processing theory (Galbraith, 1973, 1977; Daft and Lengel, 1986), contingency theory (Lawrence and Lorsch, 1967b), and research on teamwork (Gist *et al.*, 1987; Guzzo and Shea, 1992; Marks *et al.*, 2001) provide explanation of the factors playing critical role in overcoming challenges related to the networked nature of new product development.

Faced with the rapidly changing environment and the necessity to effectively manage the collaborative nature of product development, firms started to look at different strategies and tools to support their NPD efforts. Among the recently developed tools, Internet-based technologies are considered most promising and are gaining more and more popularity among both academics and practitioners involved in NPD. These technologies include mostly Internet-based networks (intranets, extranets), web-based communication technologies (e-mail, instant messaging, audio and videoconferencing), shared information space technologies (e.g. web-based document management systems, web-based team/project rooms), and integrated products designed specifically to support collaborative product development from multiple locations. It has already been widely accepted for a long time that information and communication technologies (ICT) in general can play an important role in the process of product innovation. As Corso and Paolucci (2001) argued "computer based tools can significantly enhance a firm's information processing capacity, thus improving the abilities of managing and integrating all activities which contribute to the overall process of product innovation into a value chain. (...). By facilitating knowledge transfer, emerging information and communication technologies (ICT) can also enhance learning capabilities." With the development of the Internet, it started to be more and more often postulated in the literature that especially this tool, due to its ease of access, wide availability, low cost, and common standards, has the potential to greatly improve NPD activities (Miller, 2001; Antonelli *et al.*, 2000).

As a result, numerous potential benefits have been attributed to the use of the Internet and Internet-based technologies during new product development. These benefits include, among others, more effective collection and use of information during product development, facilitation of collaboration of different people involved in product development, greater information exchange, greater participation in the NPD process, cost reduction, improvement of process proficiency, shorter new product development cycle, better access to knowledge residing in different parts of the firm, and enabling companies to undertake projects that would be too difficult or unmanageable otherwise (e.g., Ozer, 2003; Sethi *et al.*, 2003; Howe *et al.*, 2000; Mathieu, 1996). Further, from the external perspective, the low cost and advanced functionality of Internet-based technologies is believed to facilitate interorganizational NPD collaboration, R&D alliances, and supplier involvement in NPD (Primo and Amundson, 2002).

Numerous companies invested in Internet-based technologies, hoping to achieve better results in their new product development activities, i.e. especially hoping that the new solutions would enable them to accelerate product development process, increase product quality, or reduce development costs. However, in many cases the expected results were not achieved. After reviewing the experiences of companies involved in Internet-based tools for NPD, Corso and Paolucci (2001) concluded that "despite their proven technical reliability and their alleged role in supporting the process of new product development, these new applications are still offering uncertain returns and have ambiguous effects on firms' innovative capabilities." It has also been recognized that, similar to other IT technologies, the unsuccessful implementation of Internet-based technologies supporting design activities may not necessarily be caused by technical reasons, but, more often, by a lack of a clear view of the nature of the tools being implemented and of the organizational requirements needed to obtain benefits from the implementation (Chiaromonte, 2002). This is related to the fact that the technology itself – even if correctly exploited – does not produce successful innovations if the organizational and project context is not taken into account (Chiaromonte, 2002). Only when the implemented technology matches the task requirements and is accompanied by the proper organizational environment and practices, then it can be expected to positively influence the firm's performance (Chiaromonte, 2002).

Despite the vast theoretical and empirical (mostly case-study-based) research in the literature regarding the alleged role of Internet-based technologies in new product development and the increasing trend among companies to implement these technologies to support NPD activities, there is no systematic empirical evidence which would confirm that the use of Internet-based technologies leads to improvement of NPD performance. In general, there is a lack of deeper understanding of the relationship between the nature of Internet-based technology use and NPD performance. As Kessler (2003) highlights: "there has been comparatively little conceptual modelling, especially with regard to big-picture relationships, and systematic, empirical investigation into the optimization of these tools across innovation process". Therefore, there is very little systematic guidance offered to companies to help them decide which technologies are suitable for their NPD activities and how they should be applied and used to bring the most benefits. Kessler (2003) further summarized the problem: "there is scant scientific research to assess how R&D teams are leveraging the Internet in their innovation activities, if their efforts are efficient and effective, and how they could do better." The lack of such empirical evidence makes it very difficult to predict how suitable and effective the choice of Internet-based solutions for a particular NPD project may be, or will be, once these solutions are implemented. The question still remains: how can companies exploit the potential benefits deriving from implementation and use of Internet-based technologies in NPD? What are the prerequisite requirements that will enable companies to achieve these benefits? This research is the first large scale study aimed at addressing these issues.

The primary objective of this thesis is to develop and empirically test theoretical framework of Internet-based technology use during product development and its impact on NPD performance in order to contribute to a better understanding of the relationship between these two constructs. The research question under investigation is therefore "how do differences in the level of Internet-based technology use during development project influence the project performance as measured by product quality, time-to-market and development cost?" In order to answer this question, the previous relevant research in the fields of innovation, information technology and organizational theory is first reviewed and synthesized. The synthesis of the literature provides a foundation for the research model proposed in this thesis. Based on the extensive review of relevant literature, it is argued that the use of Internet-based technology leads to the improvement of NPD performance indirectly, through the improvement of communication quality, team integration and effectiveness of team learning.

In addition to testing the relationships among Internet-based technology use, communication quality, team integration, effectiveness of team learning, and NPD performance, this research aims at explaining how the role of Internet-based technologies might change based on various environmental, product and team circumstances. The moderating factors considered in this thesis include: environmental uncertainty (both technological and market), product innovativeness, product complexity, technology novelty, functional diversity in the team, team proximity, team size, and team stability. Better understanding of the role of these factors will further allow formulating guidance for companies on how to utilize Internet-based technologies to best support their NPD efforts.

This research offers both theoretical and practical contributions to the ongoing research on the NPD performance in several unique ways. First of all, from the academic perspective, it synthesizes and extends previous disparate and fragmented theoretical studies on the relationship between Internet-based technology use and NPD performance and provides a comprehensive conceptual framework of this relationship rooted in innovation, organizational theory, and information technology research. Second, this thesis proposes and tests a construct of 'Internet-based technology use during product development project'. This construct has been conceptualized and measured based on an extensive literature review in the area of information technology and innovation. Next, this study is the first to investigate empirically on large scale the relationship between Internet-based technology use and NPD performance. In this way it significantly contributes to better understanding of this relationship and factors that moderate it.

This study also offers practical contributions. It provides a benchmark of current practices regarding Internet-based technology use in NPD context. This benchmark can be very useful for companies using Internet-based technologies or considering their implementation. Further, better knowledge of the relationships that were identified and tested in this research can support companies in their decisions regarding implementation of Internet-based technologies most suitable for their individual NPD activities. A better understanding of the relationships and contingencies can help practitioners tailor the application of technologies to their individual needs and implement appropriate technologies which can further enhance their managerial and operational efficiency and lead to performance improvement. Findings from this research can help practitioners better understand their specific context and needs of their projects and therefore can help them make most of their investment in Internet-based technologies, and not limit it only to automation of selected processes. This research therefore supports companies in their decisions regarding whether Internet-based technologies are suitable for their unique NPD activities and which applications of these technologies could help them most.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature base upon which this research builds, draws from a variety of fields. It is centred in the innovation and new product development literature, but it also draws from social research, organizational behaviour, organizational theory, and information technology research. The literature review is organized around two main themes that contribute to the model proposed in this study. First of all, in order to investigate the impact of Internet-based technology use on NPD performance it is necessary to understand the new product development context. Three aspects of NPD are especially relevant from the perspective of this thesis' objectives and will be discussed in the first section of the literature review: basic definitions of NPD process and NPD performance; the collaborative nature of NPD effort; and collaboration facilitators, namely communication quality, team integration, and team learning. The second theme discussed in the literature review relates to Internet-based technology use during product development. First, Internet-based technologies applicable for NPD are identified and their characteristics are presented. The discussion of different conceptualizations of Internet-based technology use is presented next, followed by the summary of the literature explicitly addressing the impact of Internet-based technologies on NPD project and its performance. Finally, a discussion of a few key theoretical studies that model the role of Internet-based technology use in NPD context is presented. The chapter ends with conclusions highlighting the most relevant findings from the literature.

2.2 Research on New Product Development

2.2.1 Basic Concepts

2.2.1.1 NPD Process

New product development (NPD) can be defined as "the sequence of steps or activities that an enterprise employs to conceive, design and commercialize a product" (Ulrich and Eppinger, 1995). The existing models usually view new product development as a process that can be divided into a predetermined set of stages, themselves composed of a group of prescribed, related, and often parallel activities (Cooper, 1990). The identification of all the activities involved in the NPD process is not straightforward, since there is strong evidence in the literature that new product development process is not uniform across firms and products due to, among others, the different market conditions and different degrees of product innovativeness (Song and Montoya-Weiss, 1998; Ozer, 2003). As a result, there is a considerable variance in NPD processes across firms and projects in terms of the activities performed and details of each activity. Despite recognition of this variability, there is agreement in the innovation literature that although different firms may adopt different NPD processes and different products may require different processes, certain core NPD activities which are fundamental requirements for success can be identified (Ozer, 2003).

Numerous researchers attempted to identify these universal NPD activities and to develop generic models of NPD process (e.g., Booz-Allen and Hamilton, 1968; 1982; Cooper and Kleinschmidt, 1986; Cooper, 1990; Calantone *et al.*, 1997, Song and Montoya-Weiss, 1998; Griffin, 1997), see the summary in Table 2.1. In their classical work, Booz-Allen and Hamilton (1968) delineated a common six-stage process for product development which they found most typically used by firms. They observed that although certain aspects of the process were modified by firms to cater to the needs of their industry, product characteristics, or corporate culture, the generic process always consisted of the following stages: exploration, screening, business analysis, development, testing, and commercialization. In their second report, Booz-Allen and Hamilton (1982) recommended adding one more stage, i.e. 'identifying the new product strategy', to the front of the process.

Cooper and Kleinschmidt (1986) offered a more-detailed, 13-step sequence to describe the NPD process: initial screening, preliminary market assessment, preliminary technical assessments (design and manufacturability), detailed market study/market research, business/financial analysis, product development (formation of prototypes and pilot run products), in-house product testing, customer product tests, test market/local sell, trial production, precommercialization business analysis, production start-up, and market launch. Other authors, e.g. Millson and Wilemon (2002) suggested considering even more activities, such as identification of new product sources and the selection of methods for obtaining new product concepts from idea sources.

Table 2.1 Selected models of NPD process

Study	New product development process stages and activities
Booz-Allen and Hamilton. (1968)	1. Exploration 4. Development 2. Screening 5. Testing 3. Business analysis 6. Commercialization
Booz-Allen and Hamilton (1982)	1. Identifying the new product strategy 2. Exploration 5. Development 3. Screening 6. Testing 4. Business analysis 7. Commercialization
Cooper and Kleinschmidt (1986)	1. Initial screening 2. Preliminary market assessment 3. Preliminary technical assessments 4. Detailed market study/market research 5. Business/financial analysis 6. Product development (prototypes and pilot run products) 7. In-house product testing 8. Customer product tests 9. Test market/local sell 10. Trial production 11. Precommercialization business analysis 12. Production start-up 13. Market launch
Cooper (1990)	1. *Preliminary assessment*: preliminary market assessment of market size, potential and acceptance; and preliminary technical assessment of development and manufacturing feasibility, costs and times to execute 2. *Definition*: market research to determine customer's needs, competitive analysis, concept testing, technical appraisal, operations appraisal and financial analysis 3. *Development*: development of the product and detailed test, marketing and operations plans 4. *Validation*: testing of the entire viability of the project: the product itself, the production process, customer acceptance, and the economics of the project 5. *Commercialization*: implementation of both the marketing launch plan and the operations plan.
Adler (1995)	1. *Pre-project phase:* it encompasses the activities that precede the initiation of a given development project, its key output is a set of design and manufacturing capabilities: skills, procedures, technologies 2. *Product and process design phase*: includes activities required for product and process definition and its output is a set of product and process specifications, mostly in the form of drawings 3. *Manufacturing phase:* it involves activities that take place after the release of the product and process specifications to manufacturing operations and lead to creation of shippable product

Study	New product development process stages and activities
Griffin (1997)	1. *Product line planning*: analyze the firm's current portfolio vis-à-vis the competitive arena 2. *Project strategy development*: delineate the target market, determine market need, attractiveness 3. *Idea/concept generation*: identify opportunities and initial generation of possible solutions 4. *Idea screening*: sort and rank solutions, eliminate unsuitable and unattractive options 5. *Business analysis*: evaluate the concept financially, write business case, prepare protocol/development contract 6. *Development*: converting concept into a working product 7. *Test and validation*: product use, field, market and regulatory testing with customers 8. *Manufacturing development*: developing and piloting the manufacturing processes 9. *Commercialization*: launching the new product or service into full scale production and sales
Song and Montoya-Weiss (1998)	1. *Strategic planning*: preliminary assessment and integration of a project's resource requirements, market opportunities, and strategic directives 2. *Idea development and screening*: generation, elaboration, and evaluation of potential solutions to the identified strategic opportunities 3. *Business and market opportunity analysis*: execution of the marketing tasks required for converting new product ideas into well-defined sets of attributes that fulfill customers' needs and desires 4. *Technical development*: designing, engineering, testing, and building the desired physical product entity 5. *Product testing*: testing the product itself, as well as individual and integrated components of the marketing and advertising programs 6. *Product commercialization*: coordinating, implementing and monitoring the new product launch
Millson and Wilemon (2002)	1. *Predevelopment stage:* new product strategy development, identification of new product idea sources, obtaining new product concepts from idea sources, initial idea screening, preliminary market assessment/test idea, preliminary design assessment, preliminary manufacturability assessment, concept generation/determine "ideal" product, detailed market study (concept testing), financial/business analysis 2. *Development and launch stage:* development of prototypes and pilot models, development of detailed pricing, promoting, and distributing strategies, in-house product testing, customer product testing, test market/trial sell, trial production, pre-launch business analysis, production start-up, market launch 3. *Post-launch stage:* new product market strategy implementation, customer satisfaction tracking, monitoring product reinvention, suggestions/changes, observing product usage/key to redesign, tracking product maintenance/key to redesign

Study	New product development process stages and activities	
Ozer (2003)	1. Product line planning 2. Strategy development 3. Concept generation 4. Concept screening 5. Business analysis	6. Development 7. Testing and validation 8. Manufacturing development 9. Commercialization

Based on the existing research, it is possible to group NPD activities into three conceptually distinct phases of NPD process, which can be broadly called: pre-development phase, development phase, and post-development phase. The first phase encompasses the activities that precede the development work on the given project. Therefore, it includes preliminary assessment of market size, potential and acceptance; preliminary technical assessment of development and manufacturing feasibility, costs and times to execute; detailed market study (concept testing); and detailed financial and technical analysis. During this stage project planning is performed, i.e. market requirements, technology choices, and other project-related decisions are proposed, considered, and traded-off. The result of pre-development (project planning) phase is a formal or informal statement of somewhat firm product requirements, project objectives, and technology choices.

The second phase encompasses all the activities that are required to complete product and manufacturing process design and to deliver a set of product and process specifications. These activities include tasks related to the technical development and to product testing, such as: conducting preliminary engineering, technical and manufacturing assessments; building of the product to designated or revised specifications; laboratory tests to determine performance against specifications; prototyping and in-house sample product testing; determining the final product design and specifications; specifying a detailed program for full-scale manufacturing; conducting pilot production; conducting consumer trials, and testing market acceptance. The last phase of the NPD process involves activities that take place after the release of the product and process specifications to manufacturing operations and lead to creation of shippable product. It addresses both manufacturing and commercialization activities, i.e. full-scale production start-up; launching the product in the marketplace, i.e., selling, promoting and distributing; and studying feedback from customers.

Although viewing product development as a sequence of steps or stages has unquestionable value, it is important to recognize that many of these activities take place in parallel. In this regard, Calantone, Schmidt and Benedetto (1997) suggested distinguishing between activities related to the marketing side of product development and activities related to the technical development side and pointed out their parallel nature. They also stressed the ongoing importance of financial analysis which needs to be updated and reviewed as new information is collected, see Figure 2.1.

It is also important to note that models of NPD process significantly differ in terms of the range of activities considered. For example, Griffin's (1997) model starts with product line planning and strategy development activities, which are preformed early and at a higher organizational level, even before the project team is formed. On the other hand, Cooper's (1990) model starts with preliminary assessment of an idea that was already generated and approved after an initial screening. Since this thesis focuses on the teamwork processes during execution of a development project, only the NPD activities that are performed by the project team will be considered part of the NPD process.

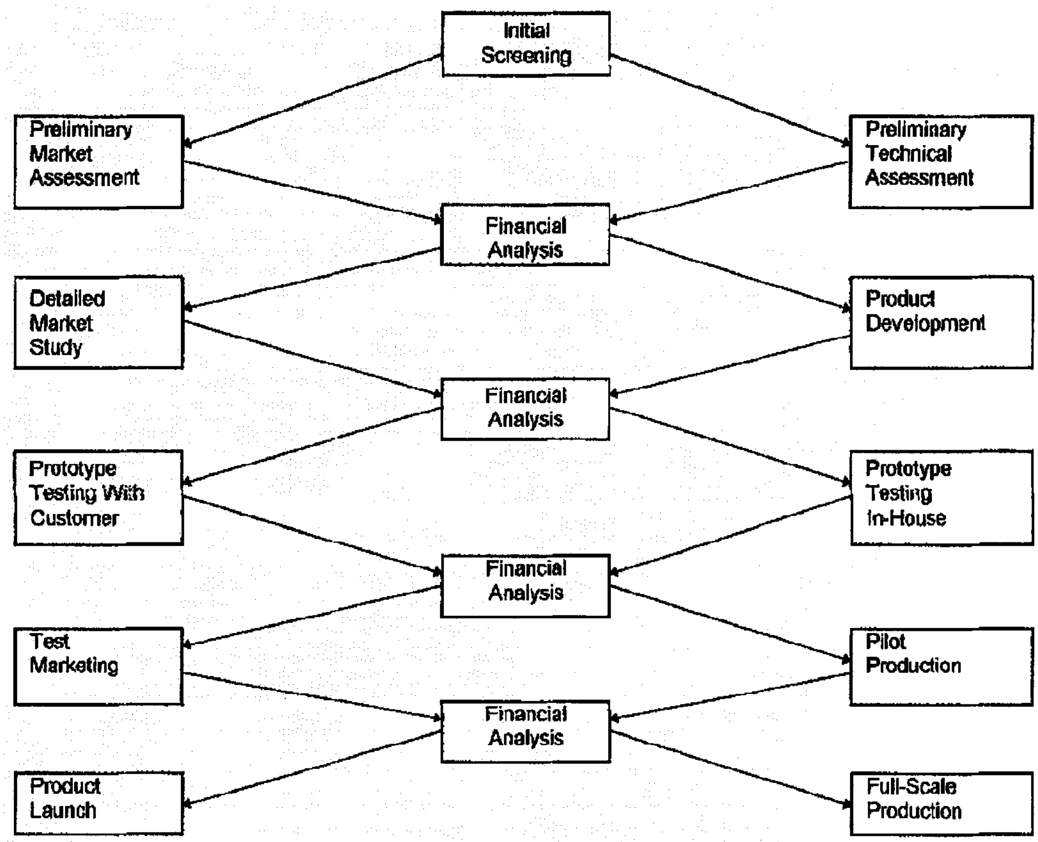


Figure 2.1 New product development process
Source: (Calantone *et al.*, 1997)

In order to assure comparability across the cases, the NPD process in the present study is conceptualized as encompassing the activities that start from preliminary assessment of an already approved idea (like in Cooper's (1990) model) and end at product launch (market introduction). This notion is reflected in the following definition of a new product development project adopted in this thesis:

A new product development (NPD) project is defined as any project involving the development of a new product, a major change to an existing product, or an incremental change to an existing product. The project may encompass activities from assessment of the product idea to market introduction.

What follows is that the present research does not address activities such as the product line planning and strategy development which are beyond the responsibility of the project team.

2.2.1.2 NPD Performance

All the activities performed during the execution of a given development project aim at delivering a successful product to the market. However, it is not straightforward to evaluate the NPD performance. Difficulties in measuring NPD performance are mostly related to the fact that, despite large number of studies investigating performance, both in general and in NPD context, there still is a visible lack of consistency in definitions. The existing definitions and conceptualizations of NPD performance build extensively on organizational performance literature. Unfortunately, also organizational performance field is characterized by significant inconsistency and lack of consensus on the definitions of terms (O'Donnel and Duffy, 2002). Numerous researchers do not explicitly define performance, despite the fact that they are investigating it (Neely *et al.*, 1995). As a result, there is “massive disagreement as to what performance is” (Meyer and Gupta, 1994) and performance “can mean anything from efficiency, to robustness, or resistance, or return on investment, or plenty of other definitions never fully specified” (Lebas, 1995).

Still, organizational performance literature provides valuable insights into the nature of NPD performance. The authors writing about performance in general either offer explicit definitions of performance (Cordero, 1989; Dwight, 1995; Neely *et al.*, 1996; Rolstadas, 1998), or discuss its specific dimensions (Clark and Fujimoto, 1991; Doz, 1996; Emmanuelides, 1993; Moseng and Bredrup, 1993). The proposed definitions of performance differ significantly in their scope. Dwight (1995) defined performance as “the level to which a goal is attained”. Other authors went further and pointed out that performance can be defined in a wider context as both the achievement of goals, and also how this achievement is obtained, i.e. they introduced the distinction between the effectiveness and the efficiency of an action (Cordero, 1989; Gleason and Barnum, 1986; Neely *et al.*, 1996). More explicitly, effectiveness reflects the extent to which an objective has been achieved, while efficiency reflects the degree to which resources have been used economically.

In case of research addressing NPD performance, only few authors provide its definition. For example, Prasad (1999) defined world class NPD performance as being achieved when the level of goodness in the products and services far outweighs the cost of processes and methodologies used in providing them. Numerous authors instead of providing a definition of NPD performance, indicate its multidimensional nature and discuss its dimensions (Clark and Fujimoto, 1991; Emmanuelides, 1993; Doz, 1996). Clark and Fujimoto (1991) argued that NPD performance consists of total product quality, lead time, and productivity (level of resources used). Emmanuelides (1993) introduced the following very similar three dimensions: total design quality, development time, and development productivity (use of resources). Doz (1996), however, presented slightly different dimensions: focus on development, speed of development and R&D efficiency. Other authors discussed also dimensions such as: quality, cost, time (Neely *et al.*, 1995), innovativeness (Danneels and Kleinschmidt, 2001; Garcia and Calantone, 2002), process maturity, synergism (occurring when an advanced technology in one area benefits another), product potential, dynamic capability (Stainer and Nixon, 1997; Eisenhardt and Martin, 2000), flexibility. Therefore, it can be concluded that the construct of NPD performance is multidimensional and companies willing to be well-performing need to excel simultaneously in its numerous dimensions (Bolwijn and Kumpe, 1990).

NPD performance can be viewed as internal (project) and external (market) performance (Hauptman and Hirji, 1996; Tatikonda and Rosenthal, 2000). NPD performance from the market-oriented perspective can be expressed in terms such as product sales levels, customer satisfaction, and market share; or the degree to which the new product enables the firm to enter a new market or take over the competitor's market share. Market-oriented measures of NPD performance are very relevant for firms and appropriate for certain research questions, but they are beyond the scope and intent of the present research. Recognizing the observation made by Hauptman and Hirji (1996) stating that it is extremely difficult to reliably trace the cause and effect from internal to external performance, this research focuses specifically on the internal, execution-oriented outcomes which can be directly affected by the execution of the project by the team.

Within the domain of the internal NPD performance, there is a need to distinguish between the product component and the process component of NPD performance. As O'Donnel and Duffy (2002) pointed out, "performance in design requires continued attention to both the design (artefact) and the activities involved in producing that design." In answer to this need Tatikonda and Rosenthal (2000) introduced the following two constructs: the product performance defined as the technical functionality, quality and reliability of the product; and the effectiveness of NPD project tasks focused on the execution-oriented outcomes, such as the degree to which a project achieves it original project/design objectives (for example cost targets, time to market targets). It is generally accepted that the three primary outcomes of new product development are time, cost, and quality (Kessler and Chakrabarti, 1996; Clark and Fujimoto, 1991; Rosenthal and Tatikonda, 1993). Although these three dimensions are conceptually distinct, they are highly correlated (Meyer, 1993). Therefore, following the previous research, NPD performance in this thesis is going to be conceptualized as a three dimensional construct composed of product quality, time-to-market and development cost.

Product quality, defined as the ability of the product or service to consistently meet or exceed customer expectations (Clark and Fujimoto, 1991), is widely recognized as a very important dimension of NPD performance, due to its influence on firm reputation and customer loyalty, on the relative attractiveness of products to customers, and ultimately on product market share and profitability (Cooper and Kleinschmidt, 1996). It has many different aspects, including: performance (main characteristics of the product or service), aesthetics (appearance, feel, smell, taste), special features (extra characteristics), conformance (how well a product or service corresponds to design specifications and to the customers' expectations), safety (reduction of risk of injury or harm), reliability (consistency of performance), durability (the useful life of the product or service), perceived quality (indirect evaluation of quality), and service after sale (warranties and handling of complaints or checking on customer satisfaction) (Garvin, 1984).

Time-to-market is also widely recognized as a relevant NPD performance dimension, significantly correlated with product quality, product's cost of development (e.g. Clark and Fujimoto, 1991; Graves, 1989; Page, 1993) and new product success (Cooper, 1986; Gupta and Wilemon, 1990; Karagozoglu and Brown, 1993; Vesey, 1991; Akgün and Lynn, 2002). Time-to-market is defined as the time elapsed between the initial product development and the ultimate commercialization, which is the introduction of a new product into the marketplace (Mansfield, 1988; Murmann, 1994; Vesey, 1991). The growing strategic importance of time-to-market is partially related to the belief that being a fast innovator can give the firm either the first-mover or the second-mover advantage, depending on which is favored by industry conditions (e.g., Lieberman and Montgomery, 1988; Emmanuelides, 1991). Given the increasingly competitive environment and demanding customers, product quality and time-to-market are becoming more and more significant determinant of competitive advantage (Dobyns and Crawford-Mason, 1991; Wheelwright and Clark, 1992).

The last dimension of NPD performance considered in this thesis, i.e. cost of development, is defined as the total financial requirements and associated human resources needed to complete the project (Rosenthal, 1992). The relationships between the dimensions of NPD performance are of ongoing interest to the researchers in this area. The discussion focuses on the dilemma whether the improvement of one dimension of NPD performance takes place at the expense of another dimension, or whether it is possible to simultaneously improve all the dimensions of NPD performance and there is no need for trade-offs. For example, some authors argued that increasing the pace of innovation reduces development costs (e.g., Meyer, 1993; Rosenthal, 1992) and improves product quality (e.g., Takeuchi and Nonaka, 1986; Wheelwright and Clark, 1992). One of the most often quoted reasons behind the positive relationship between time-to-market and product quality is related to the fact, that products introduced to the market faster can incorporate more advanced technologies. That means that products that enter the market at the same time differ: the one that made it quicker to the market includes more recent technological and scientific advances (Cordero, 1991). At the same time, other authors disagreed and suggested that trade-offs are necessary between innovation speed and the costs of development, because it may take more resources to get the product out earlier (Crawford, 1992), and between innovation speed and the quality of the product, because increasing speed may entail reducing performance specifications (Carmel, 1995; Smith and Reinertsen, 1991, 1992).

2.2.2 New Product Development as a Joint Effort

One of the most widely recognized characteristics of NPD is the fact that in order to accomplish the tasks required for the development, manufacturing and marketing of a new product, distinct specialized skills are necessary (Allen, 1986; Roberts, 1988). Since these skills usually are not possessed by one individual, successful new products are typically the result of a joint effort of many different specialists (Brown and Eisenhardt, 1995; Chiesa and Manzini, 1997; Sicotte and Langley, 2000).

2.2.2.1 Product Development Team

The specialists involved in performing NPD activities can come from one organization; however they do not necessarily come from one department. Rather, the achievement of NPD goals requires more and more the active involvement of different organizational units whose main task is neither making research nor innovating (Chiaromonte, 2002; Becker and Zirpoli, 2003). The most common way of dealing with the dispersion of knowledge required for successful completion of an NPD project and with the distribution of NPD activities across diverse organizational units, is creation of NPD teams. Team members bring diverse skills, expertise and resources necessary to perform different tasks of new product development which otherwise may be too complex or large for a single individual to complete.

Teams represent important units of work in organizations in general (Hackman, 1987). Scholars in social research define team as "a social system of three or more people, which is embedded in an organization (context), whose members perceive themselves as such and are perceived as members by others (identity), and who collaborate on a common task" (Hoegl and Gemunden, 2001; Hackman, 1987). Other authors highlight also the following characteristics of teams: interdependence of tasks of team members (Baker and Salas, 1997; Cohen and Bailey, 1997; Lipnack and Stamps, 1999), alignment of goals (Baker and Salas, 1997; Katzenbach and Smith, 1993), task orientation (Lipnack and Stamps, 1999), shared leadership (Katzenbach and Smith, 1993), shared responsibility for outcomes (Cohen and Bailey, 1997; Katzenbach and Smith, 1993), and management of team's relationships across organizational boundaries (Cohen and Bailey, 1997).

There are many different types of teams, ranging from multifunctional working groups drawn from a rigidly functional organization at one end, to a team consisting of full-time members reporting in to a full-time leader, having considerable autonomy and authority, at the other (Holland *et al.*, 2000). In the NPD context, especially cross-functional teams consisting of people from different business functions, such as marketing, purchasing, R&D, engineering and manufacturing have become increasingly popular. According to Ancona and Caldwell (1992a) a cross-functional product development team is characterized by the fact that members of different departments and disciplines are brought together under one manager and given the charge to make development decisions and enlist support for them throughout the organization. A special type of a cross-functional team is a team that is geographically dispersed across different locations locally or globally.

The need for cross-functional teams in NPD is related to the fact that the responsibility for new product introduction spans at least three functional areas within the firm: marketing, research and development (R&D), and manufacturing (Birou and Fawcett, 1994). Each functional area has its own specific responsibilities (Birou and Fawcett, 1994). In general, the role of marketing is to provide direct link with the consumer and to share, with other team members, the information regarding customer preferences and requirements. NPD team members from R&D department are responsible for providing the link to technology and designing the product so that it meets customer needs. Finally, manufacturing's role is the one of indicating what is possible in terms of manufacturability and of ensuring shortest possible response time, high quality, and dependability.

Cross-functional NPD teams have consistently been linked to development project performance and success (e.g. Clark and Fujimoto, 1991; Dougherty, 1990; Brown and Eisenhardt, 1995). They are believed to enable fast and creative responses to changing needs of development projects; to enable better understanding of clients, operations and suppliers (Boutellier *et al.*, 1998); and to improve project productivity thorough better access to multidisciplinary expertise (Leonard *et al.*, 1998; Teece, 1992; Madhaavan and Grover, 1998) and thorough enhanced learning (De Meyer, 1993a).

2.2.2.2 *Interorganizational Relationships*

Traditional NPD processes have been mostly performed within traditional organizational boundaries (Brown and Eisenhardt, 1995). However, companies are more and more often moving towards collaboration with other organizations during the execution of their NPD activities. Among the most common reasons behind the trend towards interorganizational NPD are: to achieve competitive advantage, to access new technologies or markets, to achieve economies of scale in joint research and production, to access knowledge beyond the firm's boundaries, to share risks, and to access complimentary skills. The organizations involved in interorganizational NPD often include the major manufacturer and his customers, suppliers, manufacturers of complementary products, universities and even competitors (Biemans, 2003; Chiesa and Manzini, 1997; Chiaromonte, 2002; Bittici *et al.*, 2004). Especially collaboration with major customers and key suppliers has become standard practice for world-class firms like Toyota, Honda, Motorola and Xerox (Biemans, 2003). Companies also increasingly outsource new product development activities to external organizations as part of a process called "rapid distributed innovation" or "open innovation" (Chesbrough, 2003; Carson, 2007). The popularity of outsourcing is related to its benefits for the outsourcing firm including: reduction of development costs, shorter time to market, improvement of flexibility, and access to the specialized resources of external suppliers. Outsourcing has dramatically changed new product development activity in industries such as automobiles, aerospace, computers, telecommunications, pharmaceuticals, chemicals, and software, in which product development is viewed fundamentally as a function dispersed across collaborating firms (Dahan and Hauser, 2002; Quinn, 2000; Carson, 2007).

Interorganizational NPD can take very different forms, e.g. strategic alliance, joint venture or long-term buyer-seller partnership (Gulati *et al.*, 2000). All these kinds of inter-firm partnerships can be defined as "purposive strategic relationships between independent firms who share compatible goals, strive for mutual benefit, and acknowledge a high level of mutual interdependence" (Mohr and Spekman, 1994). Inter-firm product development can be therefore defined as a formalized collaborative arrangement among two or more organizations to jointly develop a new product. These arrangements are often viewed as a potential source of value, increased productivity, innovative products, and long-term learning (Dyer, 2001; D'Adderio, 2001; Dyer and Singh, 1998).

Although in many cases NPD is conducted as a joint project of several organizations, project team still is the commonly accepted unit of analysis. It is related to the widely recognized fact that interorganizational relationships are primary executed by the means of teams (Moss-Kanter, 1994; Sambamurthy and Zmud, 2000). Based on this approach, the commonly accepted unit of analysis for interorganizational NPD processes is the "interorganizational NPD team", which can be created by two or more organizations (Moss-Kanter, 1994). Therefore, for the purpose of this thesis, the unit of analysis is a project team defined as follows:

A project team is defined for this survey as a team comprised of all the individuals who were assigned responsibility for completion of one or more project tasks. Team members include all individuals from different functional disciplines (e.g. design, manufacturing, marketing) as well as individuals from other organizations (such as customers, suppliers, partners) who were directly involved as task participants on the project, including project managers and team leaders.

The definition adopted in this thesis allows investigating both internal NPD project teams as well as project teams formed in the situation when two or more organizations collaborate on a joint NPD project.

2.2.2.3 *Collaboration Process*

Numerous researchers tried to identify factors that affect the outcomes of teamwork. Among them, Marks *et al.* (2001) pointed out that the success of teamwork is a function of team members' talents and knowledge, the available resources, and of the process team members use to interact with each other. The process of working together is the focus of the present study. As Sivadas and Dwyer (2000) stated "regardless of whether the NPD effort is an intra- or interorganizational enterprise, its success hinges on the cooperative competency of the units involved". Cooperation, or collaboration, has long been recognized as being crucial to the success of organizations (Barnard, 1938). Recent growing importance of cross-functional teams, as well as the increasing number of interorganizational and international alliances, has made joint work even more important for achieving success (Adler, 1995; Lawler, 1990; Chen *et al.*, 1998). The success of work conducted in teams depends on how well team members work together (Hoegl and Gemunden, 2001) and in order to understand the determinants of successful joint work, it is important to first explain the differences and commonalities of different conceptualizations of 'working together'.

The literature on joint work is disjointed and contradictory. There are numerous terms commonly used to describe the notion of individuals working together to accomplish a specific task. Among them are: coordination (Argote, 1982; Van De Ven *et al.*, 1976), collaboration (Trist, 1977; Jassawalla and Sashittal, 1998; Lawrence and Lorsch, 1967a,b), cooperation (Schermerhorn, 1975; Pinto *et al.*, 1993), integration (Gupta *et al.*, 1986), and interaction (Moenaert and Souder, 1990). All these constructs refer to a similar and overlapping idea of joint behaviour toward some goal of common interest. However, the literature is very confusing and often the same words are used to express different meanings or the same concepts are given different names by different authors. For the purpose of this thesis the following distinction is made. Collaboration as well as cooperation are defined as the process of working together of different individuals, groups or organizations towards a common aim (Huxham, 1996; Bittitci *et al.*, 2004; Song *et al.*, 1997; Souder and Moenaert, 1992). The difference between these two constructs is in the intensity of 'working together' with cooperation indicating smaller degree of commitment and cooperation indicating higher level of commitment of parties working together. Different projects may require different degrees of cooperation or collaboration to be executed successfully. If the entities working together are members of a team, then the process of their working together is called teamwork. This definition implies that teamwork always is collaboration (or cooperation) but collaboration not always is teamwork, only the collaboration exercised by the means of a team. Coordination, integration, and interaction are considered to be concepts different from collaboration/cooperation and will be clarified in more detail later.

In the existing literature, there is an evident lack of consensus on the definition and dimensions of collaboration or cooperation. Numerous diverse definitions of cooperation make it difficult to interpret the theory and research on cooperation. Even among the scholars who define collaboration (or cooperation) as 'the act of working together to one end', there are significant differences in interpretations of the nature of collaboration and in the main focus of analysis (Chen *et al.*, 1998). Important clarifications that shed light on the nature of collaboration and factors that constitute successful collaboration have been provided by Chen *et al.* (1998). The authors conducted an extensive literature review and distinguished between three somewhat distinctive approaches to defining and understanding cooperation, all within the common notion of 'working together towards a common goal', see Figure 2.2.

The first approach to cooperation presented by Chen *et al.* (1998) was advanced by Mead (1976) and emphasizes the participants' cooperative psychological motives of working towards the common goal and their cultural values. The second approach, proposed by Deutsch (1949a, b, 1973, 1985) and developed further by Tjosvold (1984, 1986), puts more emphasis on actual or perceived goal relationships. The theory of cooperation developed by Deutsch (1949) states that in situation of cooperation persons perceive their goal attainments as positively related; in a way that one's movement towards one's goals facilitates the others' goals. Tjosvold (1986) further made important explicit distinction between the objective goal interdependence and alignment (expressed by the task and reward structures in the organization) and the subjective goal interdependence and alignment, as perceived by organizational members.

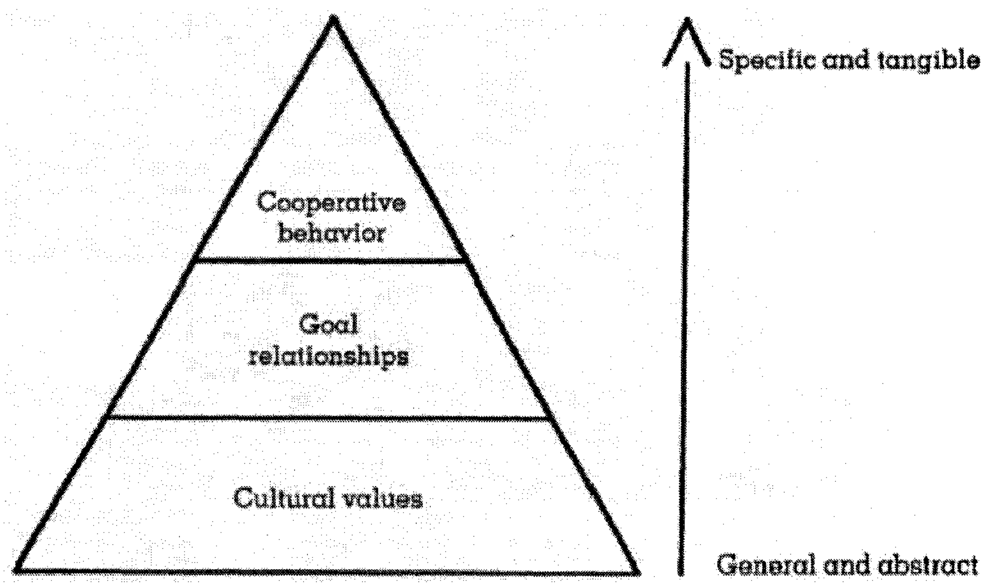


Figure 2.2 Dimensions of cooperation
Source: (Chen *et al.*, 1998)

The third, behavioral approach to cooperation focuses on different modes of engaging in a collective activity (Barnard, 1938). In his definition of cooperation, Barnard (1938) stressed the nature of cooperation as 'a functional system of activities of two or more persons' and argued that through organizing and managerial processes individual efforts can be synthesized into cooperative actions.

Each of these three theoretical approaches to collaboration provides valuable insight into the nature of collaboration and helps in better understanding of the processes that contribute to the success of a collaboration. Deutsch (1949) indicated the following processes of cooperation: expected and actual assistance, communication and influence, task orientation, and friendliness and support. Tjosvold (1986, 1988) proposed four dimensions of cooperation: exchanging and combining information, ideas and other resources; giving assistance; discussing problems and conflicts constructively; and supporting and encouraging each other. Argyle (1991) proposed that successful cooperation requires division of labor, communication, coordination, and helping.

Important insights into the nature of collaboration are also provided by the research on teamwork and teamwork effectiveness within the organizational behaviour field. This research is applicable to the special case of collaboration, i.e. collaboration executed by the means of a team, as it often happens in case of NPD projects. Teamwork research usually defines teamwork as 'people working together to achieve something beyond the capabilities of individuals working alone' (Marks *et al.*, 2001) and stresses the importance of team processes in achievement of team objectives. Team process is defined as "members' interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioral activities directed toward organizing taskwork to achieve collective goals" (Marks *et al.*, 2001). Team processes are therefore the means by which members work interdependently to utilize various resources to produce outputs. It is important to distinguish team processes from taskwork. Taskwork represents what it is that the team is doing (i.e. tasks needed to complete the activity, achieve the goal), whereas teamwork describes how team members are working together, i.e. team members' interactions (Marks *et al.*, 2001). One more aspect of teamwork identified by Marks *et al.* (2001) is represented by 'emergent states of a team', describing cognitive, motivational and affective states of teams (for example cohesiveness, leadership support), as opposed to the nature of their members' interaction. Significant contribution made by teamwork research is represented also by the different models of teamwork effectiveness (Gist *et al.*, 1987; Guzzo and Shea, 1992) which indicate the factors that contribute to effectiveness of teams. For an extensive detailed review of team effectiveness studies see Cohen and Bailey (1997).

Among the many factors contributing to successful collaboration and in particular successful teamwork, especially in NPD context, past studies have considered: communication (Strock, 2000; Child, 2001; Dyer, 2001); integration of the efforts of all the entities involved (Sicotte and Langley, 2000); integration of functional expertise represented by team members (Fruin, 1996); collective knowledge or collective mind (Baumard, 1999; Grant, 1996a; Weick and Roberts, 1993); knowledge sharing, both in terms of the specialized knowledge and knowledge of who knows what (Faraj and

Sproull, 2000; Hendriks, 1999; Goodman and Darr, 1998; Strock, 2000; Kotlarsky and Oshri, 2005); and cohesiveness and trust (Arino *et al.*, 2001; Child, 2001; Kotlarsky and Oshri, 2005). Based on the presented review of the literature addressing the collaborative nature of new product development and explaining different aspects of collaboration and teamwork, three factors contributing to successful collaboration are considered most relevant in case of NPD projects, and are hypothesized in this thesis to mediate the relationship between the use of Internet-based technologies and NPD performance: team integration, effectiveness of team learning, and communication quality. It will be shown in the following discussion that these three factors encompass most of the previously mentioned facilitators of collaboration.

2.2.3 Collaboration Facilitators

2.2.3.1 Team Integration

The definition of team integration adopted in this thesis is based on the work by Lawrence and Lorsch (1967b) and states that team integration is the degree of unity of efforts of team participants. It is important to notice that Lawrence and Lorsch's (1967b) definition of integration views it as an outcome (i.e. they focus on the state of integration defined as the extent to which unity of efforts have been achieved), as opposed to integration viewed as a process by which this state of unity was achieved. An example of the process view of integration is the definition proposed by Alsène (1999) stating that integration is "the process of forming an ensemble, a coherent whole of the various units that participate in collaboration, each of which assumes certain functions". The above mentioned distinction allows clarifying that for the purpose of this research, integration as a state is of interest.

In the existing literature there is a noticeable confusion around the concept of integration, characterized by numerous contradictory definitions (see for example Kahn and Mentzer (1996) for a review of definitions of integration) and lack of clarity in distinguishing among diverse concepts such as collaboration, integration, interaction, communication etc. In order to explain and justify the terms and definitions adopted in this thesis, some of the opposing approaches existing in the literature will be now discussed. A significant number of researchers equate integration with interaction/communication, arguing that higher number of meetings and information flows between entities involved in a given activity constitutes higher level of integration. However, for the purpose of this thesis communication is not viewed as part of integration, but as a factor contributing to integration, i.e. it is hypothesized that high quality of communication (in terms of timeliness, openness, reliability etc.) contributes to the achievement of higher level of integration (unity of efforts).

Another group of researchers equates integration with collaboration and argue that integration is equivalent with the notion of departments or individuals working collectively under common goals. However, in this thesis following subtle distinction is being made: collaboration is defined as 'working together' while integration is viewed as 'the degree of unity of efforts' of those working together. Therefore high level of integration (unity of efforts) makes collaboration (working together) more successful. This argument is consistent with the literature on success factors of collaborations which is pointing out that the failure of collaboration is often caused by lack of integration of the collaboration participants' efforts.

Even if an agreement on the definition of integration as the 'degree of unity of efforts' is achieved, there is still disagreement regarding the nature of the unity of efforts the researchers are interested in. Very often integration is broadly conceptualized as the coordination of the timing and substance of development activities performed by the various disciplines and organizational functions that span a product's life-cycle (Ettlie, 1997; Swink, 1999; Marks *et al.*, 2001). However, numerous authors argue that this definition represents too big simplification and addresses only one dimension of the integration, i.e. the coordination of activities (Souder *et al.*, 1998; Koufteros *et al.,* 2005). Souder *et al.* (1998) pointed out to the need to address also another aspect of integration, i.e. 'the team spirit of joint commitment in the performance of NPD tasks'. Koufteros *et al.* (2005) added that 'seamless and joint consideration of issues and decisions across functional and organizational boundaries' is also an important part of integration.

In order to address the concerns of the critics of one-dimensional view of integration, the conceptualization of integration adopted in this thesis builds on seminal work by Feldman (1968). After Feldman (1968), the construct of integration used in this thesis is conceptualized as having three dimensions: *functional integration* (the degree of coordination of group members' activities required to progress towards the goal), *normative integration* (the degree of consensus among group members concerning a number of group-relevant behaviours; shared attitudes concerning group-relevant matters) and *interpersonal integration* (level of cohesiveness, i.e. the reciprocal liking of group members; called in this thesis 'social integration'). These three dimensions are well established in the literature, although some authors give them different names or focus only on one of them (Hauptman and Hirji, 1999; Kahn and Mentzer, 1996).

The first dimension of integration, *functional integration,* reflects coordination of activities and in the context of NPD team refers to the degree to which timely sequencing, scheduling and synchronization of activities and tasks assigned to team members and other relevant parties has been achieved. The second dimension of team integration, i.e. *normative integration*, encompasses issues such as the degree of unity of team members' goals, behaviours, attitudes, level of mutual understanding (shared interpretation of information), having a common vision, sharing resources (Kahn and Mentzer, 1996). The last dimension of team integration, *social integration* is defined as "the attraction to the group, satisfaction with other members of the group, and social interaction among the group members" (Shaw, 1971; O'Reilly *et al.*, 1989; Simsek, *et al.* 2005). It reflects the degree to which team members are psychologically and emotionally attracted to each other and encompasses aspects such as acting cohesively, avoiding creating problems for each other, willingness to work together, trusting each other, seeking integrative solutions (Koufteros *et al.*, 2005).

Important thing to consider, when investigating integration within the NPD project team, is the number and characteristics of the involved parties. The existing research often focuses on a selected interface between two parties involved on the project and investigates integration between them. Among the interfaces most often considered are: integration between R&D and marketing (Souder *et al.*, 1998); integration between design and manufacturing (Adler, 1995; Twigg, 2002); and integration between R&D and customer (Souder *et al.*, 1998). Koufteros *et al.* (2005) further introduced separate constructs of internal integration, customer integration, supplier product integration and supplier process integration. Although it is reasonable to distinguish among these different aspects of integration, the scope of this thesis requires to consider NPD team integration as a construct encompassing the integration among all the participants in the project in general.

The importance of high levels of team integration in facilitating collaborative efforts and in improving team performance is widely stated in the literature. Several studies justify the need for different aspects of integration and provide insight into the relationship between integration and performance. The most relevant studies include works by Mintzberg (1979), Lawrence and Lorsch (1967a,b), Galbraith (1973, 1977), Thompson (1967) and Van de Ven *et al.* (1976). According to Mintzberg (1979) the need for integration (precisely functional integration, i.e. coordination of activities) arises once labor is divided in order to increase productivity: "every organized human activity (…) gives rise to two fundamental and opposing requirements: the division of labour into various tasks to be performed and the coordination of these tasks to accomplish the activity". Therefore, the moment particular tasks are assigned to different individuals for completion, it becomes necessary to introduce mechanisms for harmonizing and coordinating the work performed by each individual with that of the others. Mintzberg's (1979) work provides valuable explanation of the need for coordination; however, it fails to explain the differences in the levels of integration required under different circumstances. This question is investigated in more detail by the contingency theorists.

According to the contingency theory the need for integration within NPD project and its positive impact on performance can be explained through an analysis of technological and environmental uncertainty (Lawrence and Lorsch, 1967a), information-processing requirements (Galbraith, 1973), or task interdependence (Thompson, 1967; Van de Ven *et al.*, 1976; Pinto *et al.*, 1993). Contingency theory based on the first concept indicates that in response to technological and environmental uncertainty organizations introduce differentiation and specialization (Lawrence and Lorsch, 1967a). The greater the uncertainty an organization faces, the greater the functional differentiation and specialization this organization is likely to incorporate in order to be able to better cope with the environment. Specialization supports achievement of organization's goals in situation of uncertainty, because it enables the firm to empower functional groups to address the uncertainty that is related to their fields. In NPD context specialization means that R&D specialists will focus on resolving problems related to new technologies, while marketing specialists will deal with uncertainties related to market and consumer preferences. At the same time, however, as Gupta *et al.* (1986) and others pointed out, functional specialization creates coordination difficulties. Therefore, the higher the levels of market or technological uncertainty and the greater the organizational specialization introduced as a response to it, the greater the need for coordination of efforts across units involved in the project and the more crucial role of integration in achievement of high levels of performance.

Galbraith (1973, 1977) explained the need for integration through the information processing theory. This theory states that every organizational task poses information processing requirements to the organization. Information processing requirements increase as a function of increasing uncertainty, i.e. the greater the level of uncertainty associated with the technology and the market environment, the greater the amount of information that must be processed in order to reduce this uncertainty and complete the task (Galbraith, 1973; Tushman, 1978; Daft and Lengel, 1986). Task uncertainty depends on task-specific characteristics and is also organization-specific: what is certain to one organization may be uncertain to another (Sor, 2004; Galbraith, 1977). Gupta *et al.* (1986) applied information processing theory to the NPD context and argued that uncertainty increases the need for interconnected product development practices that help product development teams cope with the fuzziness of their task environment. However, increased need for interconnected product development practices means more challenges in achieving integration of the efforts of all the participants. Therefore, greater uncertainty and related to it greater information-processing requirements result in higher need for integration effort. However, if higher levels of integration can be achieved, they will facilitate uncertainty reduction through information processing and therefore will contribute to NPD performance.

Finally, another group of researchers (Thompson, 1967; Van de Ven *et al.*, 1976; Pinto *et al.*, 1993) argued that the need for coordination stems from the complex interdependencies among team members working together towards a common goal. When there are significant interdependencies among the tasks, it also becomes more difficult to coordinate the individuals who have been assigned the tasks. Therefore, greater interdependence of work process and technology requires greater integration effort.

All the above discussed theories are complimentary in their explanation of the contingencies of the need for integration. There is more need for integration when there is greater uncertainty, greater interdependence of tasks, greater project complexity or greater information processing requirements. It is also generally accepted in the literature that team integration is a significant contributor to team performance. However, some authors argue that its importance can vary significantly across different projects. If members of a team can work independently and there are no task dependencies, then there is no significant need for integration and it will not affect performance, at least not substantially (Malone *et al.*, 1994; Thompson, 1967; Van de Ven *et al.*, 1976). Conversely, when multiple specialists, sub-tasks and resources need to interact in a synchronized way in order to complete a task, there will be substantial interdependencies requiring to be managed and as a result integration can be expected to play significant role in supporting performance.

While the high level of integration of all individuals involved in NPD project may be in many cases necessary for achievement of high NPD performance, it may not always be a sufficient condition of NPD success (Tessarolo, 2007). Achieving the optimal levels and modes of integration will only create the appropriate structural conditions (Sherman *et al.*, 2005). In order to achieve high levels of performance in new product development, an effective process of team learning is also very important (Sherman *et al.*, 2005; Ozer, 2004).

2.2.3.2 Effectiveness of Team Learning

Over the last decade NPD team learning has been receiving great attention in practice as well as in academia due to its perceived important role in facilitating new product performance and success (e.g., Purser *et al.*, 1992; Brooks, 1994; Hughes and Chafin, 1996; Edmondson, 1999; Akgün *et al.*, 2002; Lynn, 1998; Lynn *et al.*, 2000; Döös *et al.*, 2005; Koners and Goffin, 2007). Team learning is considered critical in new product development because innovation usually spans many functional areas, including engineering, marketing, manufacturing, finance, etc., and as a result the team frequently is composed of heterogeneous individuals who must interact and learn from each other (Lynn *et al.*, 2000). Learning is vital in new product development also because development teams must respond to rapidly changing technologies, customer needs and competitive actions (Lynn *et al.*, 2000; Meyers and Wilemon, 1989). Information use associated with learning is believed to lead to the detection and correction of errors (Argyris and Schön, 1978) and overall improvement of the likelihood of effective new product development in a firm.

Team learning literature builds on organizational learning research (Fiol and Lyles, 1985; Levitt and March, 1988; Huber, 1991) and at the same time borrows heavily from the field of individual cognition and learning (Lynn *et al.*, 2000). Learning has been conceptualized as both an outcome (e.g., Levitt and March, 1988) and a process (e.g., Argyris and Schön, 1978). Organizational learning is widely viewed as a multistage process of information acquisition, information dissemination, and shared interpretation (Sinkula, 1994). Building on this definition, numerous authors offered different conceptualizations of team learning; often complementary in their nature. Huber (1991) conceptualized team learning as the degree to which processing of team experience changes the nature and range of team actions. Complementary conceptualization of team learning defines it as the construction of collective new knowledge (Brooks, 1994; Kasl *et al.*, 1997). Brooks (1994) has further identified the following processes of team learning contributing to the creation of new knowledge: problem-posing; sharing knowledge and ideas; integrating new knowledge; gathering data; and disseminating new information. Kasl *et al.* (1997) pointed out that the new knowledge is created not only for the team members, but also for others and suggested that team learning includes the following processes: perception of issues based on inputs or past experiences; transforming those perceptions into new understanding; experimenting; and seeking and/or disseminating information with other individuals or units.

Quite a few conceptualizations of team learning view it as multidimensional construct consisting of information/knowledge acquisition, knowledge sharing and knowledge implementation (Edmondson, 1999; Lynn *et al.*, 2000; Garvin, 1993; Adams *et al.*, 1998). Edmondson (1999) argued that team learning can be viewed both as the processes and outcomes of group-interaction activities through which individuals acquire, share, and combine knowledge, including the following processes: asking questions; seeking feedback; sharing information; experimenting; and discussing errors or the unexpected outcomes of actions. Edmondson (1999) defined team learning behavior as comprising "activities carried out by team members through which a team obtains and processes information that allows it to adapt and improve". Lynn *et al.* (2000) agreed with defining team learning as a process of knowledge generation, dissemination, and implementation and in empirical research demonstrated that team learning processes involve recording, filing, and retrieving information, as well as developing common, stable, and supported goals for projects.

Approach developed by Lynn *et al.* (2000) was further extended by Akgün *et al.* (2002) who focused on the collective nature of team learning. They argued that team learning is a collective activity rather than individualistic, since team members encode, interpret, and recall information together rather than apart (Argote, 1999; Madhavan and Grover, 1998) and pass their knowledge to each other to accomplish their tasks more effectively (Cicourel, 1990; Martin and Clark, 1990). As a result, Akgün *et al.* (2002) stated that team learning involves social cognition and used its components to explain and define the construct of team learning. The social cognitive activities they considered include: acquiring, disseminating and implementing information; discarding old information (i.e. unlearning); storing information and skills (i.e. memory); manipulating memory (i.e. thinking); action learning (i.e. improvisation); information processing ability or capability (i.e. intelligence); and giving meaning to information (i.e. sensemaking). Based on the empirical study of 124 NPD projects they confirmed the multidimensionality of team learning.

In continuation of their research, Lynn *et al.* (2003) discussed concept of accelerated team learning, defined as faster construction and dissemination of collective new knowledge. The distinction between traditional team learning and accelerated team learning is that accelerated learning considerably speeds-up learning through the process of doing, acting, and sharing information and knowledge quickly. Features or processes of accelerated learning derived from traditional learning for teams are: adapting and responding to environmental changes quickly; acquiring information about customers and competitors quickly; processing and disseminating such information rapidly; and using technology and other methods more efficiently for a successful NPD project. Another recent study looking at team learning processes in new product development context, conducted by Döös *et al.* (2005), investigated software development engineers working at the interface between tele- and datacom within Ericsson in Sweden. The research identified three types of learning processes in which employees engaged to accomplish their tasks: learning basic knowledge; co-creating new knowledge; and learning changing-knowledge.

Based on the above discussion of literature, for the purpose of this thesis, team learning is defined as the collective activity of gathering, retaining, sharing, interpreting, and applying knowledge during a project execution to address project tasks and problems in order to achieve the common goal of the team (Nonaka and Takeuchi, 1995; Grant, 1996b; Meyers and Wilemon, 1989; Edmondson, 1999). It is further conceptualized to consist of three dimensions: information/knowledge acquisition; knowledge sharing; and knowledge application (Adams *et al.*, 1998; Moorman and Miner, 1997). Effective team learning should lead to new knowledge and experience available to team members, which should then lead to effective decisions and actions. In the case of product development teams, whose work is significantly non-routine, effective decisions would involve responding adequately to changing task requirements.

In order to further clarify the definition of team learning adopted in this thesis, it is necessary to define and explain the term 'knowledge'. This term is widely used in academic literature within many domains, including psychology, sociology, strategic management, and management of technology to name a few. It is generally distinguished from data and information (Davenport and Prusak, 1998). Data represent "observations or facts out of context, and therefore not directly meaningful" (Zack, 1999). Information, on the other hand, is data which is organized and presented in context, and which can be meaningful and relevant for a given recipient (Roberts, 2000). Finally, knowledge is defined as "a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates as is applied in the minds of knower" (Davenport and Prusak, 1998). Therefore, knowledge presupposes information, and information presupposes data (Bakker *et al.*, 2006). Following this conceptualization of knowledge, the individual is viewed as an information processing system who receives data and information from the environment and creates knowledge through interpretation (Newell and Simon, 1972).

Therefore, knowledge can be viewed as the information given meaning by knowledgeable agents (Fleck, 1997). There are many more definitions of knowledge in the innovation and technology management literature, stating that knowledge is "a justified, true belief" (Nonaka and Takeuchi, 1995); "information whose validity has been established through tests of proof" (Liebeskind, 1996); "information that is contextual, relevant and actionable" (Soliman and Youssef, 2003); "the shared set of beliefs about casual relationships among phenomena held by individuals within a group" (Sanchez *et al.*, 1996). Bakker *et al.* (2006) distinguished among the following four categories of knowledge most relevant in the context of product development: knowledge on how to do things, know-how (procedures, processes, etc.); knowledge on who are in the organization, for example whom to turn to with a certain question; knowledge on the task (know-what) itself, i.e. task-related facts, models, specifications, etc.; and knowledge on why things are done (background knowledge). Important aspects of knowledge highlighted in the above definitions include the relevance of the information and its subsequent application for decision making and problem solving. Given the definition of team learning as information/knowledge acquisition, knowledge sharing, and knowledge application which was adopted in this thesis, it is also important to specify that this definition refers to both the knowledge acquired from the team environment and the knowledge generated during the project that is relevant and needed for effective completion of project tasks and achievement of project objectives.

A concept that is very closely related to knowledge and team learning is knowledge management. Many researchers have noted and discussed the close relationship between knowledge management and organizational learning (Bennet and Tomblin, 2006). Knowledge management is viewed as being more about techniques for applying and accumulating knowledge while organizational learning is more about learning process. Birkinshaw (2001) claims that organizational learning was the forerunner of knowledge management and that their underlying premise is similar. Given the scarcity and value of knowledge, organizations must become better at learning if they are to succeed (Bennet and Tomblin, 2006). López *et al.* (2004) further see knowledge management as a process that facilitates knowledge sharing and exchange and establishes learning as a continuous process within the organization.

Product innovation is widely viewed as an information processing activity (De Meyer, 1985; Moenaert *et al.*, 2000) and as a result numerous authors strongly argue that the success of an NPD project is directly related to the success with which knowledge is disseminated and created by members of NPD teams (Söderquist, 2006). Numerous studies have postulated and have shown the important role of team learning in NPD (see Sarin and McDermott, 2003; Bakker *et al.*, 2006). It has been hypothesized that team learning influences NPD performance (Edmondson, 1999) because it helps to create more effective routines, to better address the complexities of organizational, technological, and environmental factors (Cohen and Levinthal, 1990; Fiol and Lyles, 1985; Nelson and Winter, 1982) and to perform future activities more efficiently (Arrow, 1962).

2.2.3.3 <u>Communication Quality</u>

Within the communication model, communication is defined as a process in which a source transmits information to a receiver through one or more channels (Rogers and Agarwala-Rogers, 1976). It is widely recognized in the literature that in order to achieve the goals and benefits of collaboration, effective communication between partners is essential (Cummings, 1984; Mohr and Spekman, 1994). Especially in the context of NPD communication has received significant attention (Allen, 1985; Rogers and Shoemaker, 1971; Rogers and Agarwala-Rogers, 1976). The NPD research addressing communication has evolved from the pioneering work of Allen at MIT (1971, 1977) which underlying premise is that communication among project team members and with outsiders improves the performance of development teams.

This role of communication is related to the fact that communication provides a means for the exchange of information among team members and between team members and their environment (Pinto and Pinto, 1990). During the development process, data on market opportunities and technical possibilities are created, screened, stored, combined, decomposed and transferred among various media, including human brains, paper, computer memory, software and physical materials (Clark and Fujimoto, 1991). Communication flows across firms horizontally, from the customer perceptions to the final product involving all the functions of the process chain, and vertically, from the top management to the workers. Additionally, NPD team members often come from different functional departments or even organizations and possess knowledge about nonoverlapping aspects and stages of the project; however, they do not view the knowledge they have in the same way (Patrashikova-Volzdoska *et al.*, 2003). These differences can lead to varying interpretations of the same information that needs to be communicated in order for the team to work effectively.

Communication is considered especially critical in situation when the development project is highly complex, faces high levels of uncertainty or involves participants from widely distributed geographical areas, sometimes on different continents (Calabrese, 1999). Explanation of the important role of communication in these scenarios is provided by the information processing theory, which views communication as a significant facilitator in dealing with uncertainty and functional interdependencies during the information processing required by the given innovation project (Thompson, 1967; Tushman, 1979a,b; Tushman and Nadler, 1980; Souder and Moenaert, 1992).

It is therefore widely argued in the innovation research that successful teamwork and high performance in NPD context depend to large degree upon the quality of the communication during the project execution (Allen, 1985; Clark and Fujimoto, 1991; Moenaert and Souder, 1990). This relationship was tested empirically in several different contexts. Souder (1988) conducted a 10-year study of 289 projects and provided evidence that inter-functional communication strongly correlates with NPD success. Dougherty (1990) conducted study of nine pairs of successful and unsuccessful new product projects and discovered that sporadic communication among team members was associated with failed products and consistently frequent and effective communication across many topics among team members was associated with successful products.

Cooper (1996) found that successful teams interact and communicate well and often. Pinto and Pinto (1990) pointed out that the main reasons for communication in effective teams were brainstorming, obtaining project-related information, reviewing progress and receiving feedback, rather than resolving interpersonal differences. The role of communication, especially the two-way interactive feedback mode, was found to be an essential determinant of performance in product development teams in terms of level of innovation (Ancona and Caldwell, 1992b), project effectiveness (Brodbeck, 2001; Keller, 2001), and patents and commercialized products (Allen, 1985; Visart, 1976).

All the above mentioned studies investigated different aspects of communication, such as frequency, openness, effectiveness, etc. Generally, communication is considered to be effective if the following two requirements are met: the source has the intent to share the information and the information transmitted generates a change in the receiver's knowledge, attitude or behaviour that was intended by the information source (Rogers and Shoemaker, 1971; Rogers and Agarwala-Rogers, 1976). For communication to be efficient, the intended communication effects must be obtained at the lowest cost possible (Moenaert *et al.*, 2000). The effectiveness of communication depends on the quality of the communication. For the purpose of this thesis, communication quality during the NPD project is defined, after Lievens and Moenaert (2001) and Moenaert *et al.* (2000), as the degree to which relevant and understandable information reaches the intended information receivers in time. In NPD literature communication quality has been conceptualized to include aspects such communication amount (Van de Ven *et al.*, 1976), frequency (Argote, 1982; Hoegl and Gemuenden, 2001), formalization (Hoegl and Gemuenden, 2001), openness (Hoegl and Gemuenden, 2001; Hoegl and Wagner, 2005), timeliness (Waller, 1999; Hoegl and Wagner, 2005), accuracy (O'Reilly and Roberts, 1977; Hoegl and Wagner, 2005), reliability (Hoegl and Wagner, 2005), adequacy and credibility (Daft and Lengel, 1986; Huber and Daft, 1987; Stohl and Redding, 1987; Mohr and Spekman, 1994).

Some of the aspects of communication quality are straightforward, while others require further clarification. Frequency (also called interchangeably 'quantity') of communication describes the amount of communication that occurs among participants, i.e. answer the question of how extensively team members communicate (i.e. time spent communicating). The longer and more intensive the contacts using various modes of communication (e.g. phone, mail, electronic mail, face-to-face), the higher the quantity of communication (Hoegl and Wagner, 2005). Degree of formalization refers to the extent of how spontaneously team members are able to converse with each other. Formal communication is the communication that requires a large amount of preparation and planning before it can occur (e.g. scheduled meetings, written status reports). Informal communication, on the other hand, is spontaneously initiated and encompasses, for example, talks in the hallway, short e-mails, quick phone calls (Hoegl and Gemuenden, 2001). Informal communication is considered particularly crucial to the work of teams developing innovative products, since it allows ideas to be shared, discussed, and evaluated among team members more quickly and efficiently (Katz and Allen, 1982; Pinto and Pinto, 1990; Brodbeck, 2001).

Another very important aspect of communication quality is its openness, i.e. the degree to which important information is shared as opposed to being held back (Gladstein, 1984; Pinto and Pinto, 1990). Its importance for teamwork is widely recognized, because lack of openness of communication hinders the integration of team members' knowledge and experience on their common tasks. Honest and open communication, on the other hand, improves close ties among team members (MacNeil, 1981). Based on the findings and recommendations from the innovation literature, for the purpose of this thesis communication quality is defined in terms of timeliness, reliability, openness, accuracy, and effectiveness of communication among team members (Mohr and Spekman, 1994).

2.3 Research on the Use of Internet-based Technologies in New Product Development Context

As it was stated before, the research objective of this thesis is to investigate the role of Internet-based technologies in NPD, specifically in terms of their impact on NPD performance. It is hypothesized that this impact is not direct, but mediated by the above discussed three facilitators of team collaboration, namely communication quality, team integration and team learning. The following section will discuss the existing literature that provides foundation for the hypotheses formulated in this thesis and will provide explanation of the role of Internet-based technologies in product development projects.

2.3.1 Evolution and Classification of Internet-based Technologies for NPD

The Internet and Internet-based technologies (IBT) have been receiving a significant attention from practitioners and academics for over 15 years, since the Internet became publicly available. The early studies focused mostly on the design and modelling aspects of these technologies. As more technologies and applications have diffused into the industry, a growing number of case studies on the implementation and use of these technologies in organizational settings have been conducted. However, there is still lack of agreement on the all-encompassing list of the Internet-based technologies or their potential classification. It is to large extent caused by the fact that these technologies evolve and merge very rapidly, all the time creating new possibilities and challenges for companies interested in their different applications. Still, despite the lack of agreement, existing literature provides valuable insight into the nature and evolution of Internet-based technologies as well as their changing functionality in the NPD context.

The Internet is the foundation for the other tools discussed in this section. It is defined as "a public and global communication network that provides direct connectivity to anyone over a local area network (LAN) or Internet service provider (ISP)" (Turban *et al.*, 2000). The beginning of the Internet can be traced to late 1969, when the Advanced Research Project Agency (ARPA) connected four computers to form the initial ARPANET (Turban *et al.*, 2000). The growth of the Internet use began in the late 1980's with the development of standard protocols and core technologies enabling communication across different computer platforms and software applications.

Introduction of hypertext markup language (HTML), transport-control protocol (TCP), Internet protocol (IP), and other open standards have facilitated further development of the Internet and Internet-based technologies. Computers connected to the Internet are able to communicate with each other because they use the Internet protocol as a common method for routing and transferring messages across computers. The significant difference between the Internet protocol and other forms of computer networks is that the open standard of the Internet allows integration between many incompatible applications and legacy systems.

The focus of this study is not only the Internet, but also Internet-based technologies, which are defined as technologies using the Internet protocol to connect. Over the last 15 years numerous Internet-based technologies and tools have been developed. They include a variety of electronic communication and collaboration technologies, such as electronic mail and news services to send messages to other users; the World Wide Web; intranets and extranets; telnet services to work on remote computers; file transfer to access and retrieve files from remote computers; text-based and voice-based chat; EDI-Web systems; B2B portals and many others (del Aguila Obra *et al.*, 2002). The list presented here is not all-encompassing, because these technologies evolve very rapidly and are all the time updated with new versions offering their users increased functionality and new possibilities. It is important to note that numerous Internet-based technologies are being developed and tailored specifically to support NPD activities. In this section, Internet-based technologies most applicable to NPD context will be discussed and explained in more detail. Although they do not represent an all-encompassing list, they cover most of the functionality that is relevant for NPD activity. Their classification is based on the approach proposed by Munkvold (2003).

2.3.1.1 Network Infrastructure

The first group of Internet-based technologies very relevant in the NPD context encompasses Internet-based networks. The quality of the network infrastructure in an organization, regarding its performance, stability, and compatibility can have significant impact on the implementation and functionality of other Internet-based tools (Munkvold, 2003). The first organization-specific networks to evolve from the Internet were *intranets* – internal organizational networks modeled on the World Wide Web (a point and click hypertext interface developed for the Internet) but, unlike the Internet, private and protected from public by security systems (McIvor *et al.*, 2002). Many intranets were initiated by companies with the goal of distributing information relevant for its employees by publishing it on the intranet, instead of publishing and distributing hard copies. In this way intranets can rapidly lead to reduced cost of producing and distributing printed information within the organization. These benefits of intranets are especially visible in situations when the distributed information becomes quickly outdated and there would be high costs of updating hard copy documents. Intranets can also lead to development of an online virtual workplace which will be discussed in more detail later. Applications of Intranets to new product development are further discussed in (Piippo *et al.*, 2003).

Extranets, i.e. external business networks, represent another type of Internet-based network. They link a group of organizations over the Internet using the TCP/IP protocol. Extranets provide secured connectivity between an organization's intranet and the intranets of its business partners, suppliers, customers, financial service providers, or government. The extranet is an open and flexible platform that enables connectivity between organizations through the Internet and allows groups to work together and share information exclusively and securely. Access to information can be controlled by use of password protection so that different users can have access to information designed for them. Extranets allow organizations to work together more closely than older technologies such as electronic data interchange (EDI), which were based on a closed set of standards that required a significant investment in infrastructure (McIvor *et al.*, 2002). An enhanced form of extranet is *Virtual Private Network* (VPN). It connects remote employees, customers, or partner organizations over the Internet providing high degree of security for the data and the users (the security is provided by encryption).

2.3.1.2 Teleworking

Teleworking involves the complete or partial use of ICT (in case of this thesis the focus is on the Internet) to enable workers to get access to their work activities from different and remote locations (Martínez-Sánchez *et al.*, 2006). The empirical evidence indicates that teleworking is quite frequent among the new product development activities. The report on e-work in the European Union showed that the two main functions performed remotely through the use of IT are the software development and maintenance, and the design and development of multimedia (Huws *et al.*, 2001). Similarly, Edwards and Edwards (1995) confirmed that jobs frequently performed remotely with the use of information technologies include software development and computer aided design.

2.3.1.3 Communication Technologies

The next category of Internet-based technologies encompasses communication technologies, including both asynchronous and synchronous technologies that support interpersonal communication across geographical distance but do not provide functionality for information processing (Munkvold, 2003). These tools used by organizations for online discussions include mostly: e-mail, instant messaging/interactive chat tools (enabling direct real-time interaction between a limited number of participants), voice over IP (an Internet protocol that facilitates real-time voice communication over the Internet), and Web conferencing (enabling virtual meetings between dispersed members).

The basic and most widely used Internet-based tool is electronic mail, i.e. the exchange of computer-created and computer-stored messages via a telecommunications network, such as the Internet or other private or public networks based on the Internet. Electronic mail was one of the first uses of the Internet and is still among the most popular of them. Some authors argue that e-mail communication can lead to better decision processes, because enables people to provide more reflected input than in synchronous, face-to-face communication. Also, it can provide messaging services for coordination of activities (Munkvold, 2003). Despite the popularity of e-mail, this mode of communication has certain limitations, such as the fact that its asynchronous nature makes it difficult to have conversation with another person. Instant messaging (IM) overcomes the limitations of electronic mail and enables its user to verify whether a given person is online and to exchange text messages in near real time. Most IM products also include functions for establishing chat rooms with friends and co-workers, for exchanging files, and for conducting audio- or videoconferences (Munkvold, 2003).

Audioconferencing and videoconferencing constitute another very popular Internet-based communication technology. Videoconferencing combines advantages of phone call with the added benefit of actually seeing all the participants located at multiple locations through a video link. Videoconference can take place between two or multiple locations, with one person or a group of people at each location. The main features of videoconferencing include the ability to hear the verbal messages as well as to see the nonverbal messages of the speakers. Also, visual aids in the form of charts, posters, overhead projections can be incorporated into the videoconference. Videoconferencing is claimed to reduce miscommunication, support team building, especially in the early stages of the team formation. Recent developments in PC-based desktop videoconferencing and desktop conferencing systems make it more accessible.

2.3.1.4 Shared Information Space Technologies

Shared information space technologies is the common term used for technologies supporting collaborative work related to creation and manipulation of information objects such as documents and drawings, and for creating virtual interaction spaces such as electronic bulletin boards and discussion lists (Munkvold, 2003). They include mostly different Internet-based product design systems, such as web-based collaboration systems/project rooms (Tsai *et al.*, 2006), web-based product data management systems (Roy and Kodkani, 1999; Rezayat, 2000; Gianni *et al.*, 2002), and collaborative CAD tools (Li *et al.*, 2005; Tay and Roy, 2003; Shyamsundar and Gadh, 2002). They are often used as part of integrated systems, which will be discussed later. Generally these systems were limited in their use in the sense that they allowed distribution of product information only among design participants having proprietary or high-end software systems. However, new technologies are been developed to enable also participants without these systems (such as customers, marketing staff, small suppliers) to participate in the design activities. One promising technology is the Web-based collaborative visualization (WCV) (or 3D Web viewing), which enables the user to visualize, annotate, and control 3D design model interactively over the Internet. Its benefits and applications are discussed in (Chu *et al.*, 2006). Commercial software tools from this category, such as AutoVue™ and SpinFire™ have already been successfully deployed in many industrial applications.

2.3.1.5 Project Management Technologies

This group of technologies includes Web-based workflow management systems and online calendars and meeting schedulers. Workflow management systems is the common term used for technologies that support the automation of work processes by routing information among the different actors according to a predefined sequence representing the process (Munkvold, 2003). Workflow management systems based on the Internet/web platform enable participants in the work processes to access their job queues and perform the tasks through a web browser.

2.3.1.6 Integrated Products

This category covers products that incorporate functionality across other categories, typically some combination of communications, shared information/work space and project management technologies. These products usually comprise a comprehensive range of tools/applications, as well as serve as a network infrastructure. Common examples of integrated collaboration product include Lotus Notes/Domino and Microsoft Exchange/Outlook. This group includes also the web-based software packages created for the purpose of supporting NPD, such as Metaphase or Windchill (Sethi *et al.*, 2003). Several examples of web-based NPD software are compared in Table 2.2.

Table 2.2 Selected examples of Internet-based NPD software

Software	Company	Website	Brief Description
Metaphase	EDS	http://www.sdrc.com/metaphase/index.shtml	Metaphase is a product data management (PDM) software that is comprised of modules that enable data management and control, product definition, automation of NPD processes, collaboration with external partners, and searching for product-related information
Windchill	PTC	http://www.ptc.com/products/windchill/index.html	Windchill is a web-based suite of collaborative software applications for product development. It enables integration of NPD processes and product data with dispersed divisions, partners, and customers.
Enovia	IBM	http://www-3.ibm.com/solutions/plm/pub2/	Similar to Metaphase and Windchill, Enovia is a PDM software suite. It deploys the Internet to share NPD data among internal departments, external partners, and customers.
iNotebook	NexPrise	http://www.nexprise.com	iNotebook is a module of the software ipTeam that is used for creating virtual product development teams. The software facilitates communication between NPD partners as it manages documents, messages, and supplier data.

Source: (Sethi *et al.*, 2003)

Integrated products usually offer wide functionality encompassing, among others, product data management with remote access by all team members, automation of NPD processes, involvement of external partners, and communication among team members.

The above discussion of the Internet and Internet-based technologies resulted in the following definition adopted for the purpose of this thesis:

Internet-based technologies are defined widely as web-enabled or Internet-enabled technologies or tools using Internet protocols. They include a variety of electronic communication, information/data management, and collaboration tools (e.g. electronic mail, instant messaging, videoconferencing, Intranets, Internet-enabled project workspaces/systems/tools, distributed virtual networks and file sharing systems, web-enabled groupware, or design or modeling tools for distributed teams etc.).

2.3.2 The Use of Internet-based Technologies in NPD Projects

The degree to which different companies use the Internet and Internet-based technologies in their activities varies significantly. However, many studies of the impact of the Internet and/or Internet-based technologies on different company's operations do not consider the extent of use of the technology of interest, but simply distinguish between its 'adopters' and 'non-adopters'. In order to investigate the impact of Internet-based technologies on NPD performance it is necessary to first define and explain the construct of Internet-based technology use in NPD context and to distinguish between different degrees of Internet-based technology use.

Defining and measuring Internet-based technology use is not a simple task and there is no agreement in the literature how it should be addressed. There are not many frameworks addressing Internet-based technology use and the existing ones are usually rooted in the literature on IT use in general. It is very relevant to review literature on IT use first: the frameworks from the IT literature are well established and can be used and applied in the context of Internet-based technologies given that Internet-based technologies are a subset of information technologies. Therefore, in order to clarify the conceptualization and measurement of Internet-based technology use for the purpose of this study, the literature on IT use will be reviewed first and then the use Internet-based technologies in NPD context will be discussed.

The broad concept of IT use have been considered and measured from several different perspectives (DeLone and McLean, 1992; Mahmood *et al.*, 2001). Its definition, dimensions and measures have significantly changed over time, following the changes in the nature and the potential of the available information technologies. Five major stages in the development of IT use construct can be distinguished, see Table 2.3.

Early empirical studies of IT use usually viewed IT use as a one dimensional construct and in order to measure it they employed simple objective measures, such as: *use versus non-use variable* (Alavi and Henderson, 1981; DeBrabander and Thiers, 1984), different types of *frequency of use*, including frequency of requests for specific reports or information, frequency of past and intended use, frequency of general and specific use

(Benbasat *et al.*, 1981; Culnan, 1983; Ein-Dor *et al.*, 1981; Fuerst and Cheney, 1982), *time IS was used*, measured in terms of hours per week, number of minutes, time per computer session (Ginzberg, 1981; Snitkin and King, 1986; Srinivasan, 1985), and *number of computers used.*

Table 2.3 Five development stages of the IT use construct

Stage	Construct definition and dimensions	Measures
Stage 1	One-dimensional construct	Use vs. non-use variable or single, objective measures such as: frequency of use, number of computers, number of requests, time.
Stage 2	Multidimensional construct In addition to *frequency of use*, the dimension *nature of IT use* (what IT is used for) was added	In order to measure *nature of IT use* single measures were used, such as: number of features or functions used, nature of queries.
Stage 3	Multidimensional construct The dimension *nature of IT use* (what IT is used for) was added, way of measuring it has changed	In order to measure *nature of IT use* multiple-item variables were introduced, listing different areas of IT use in organization
Stage 4	Multidimensional construct IT implementation models allowed distinguishing clearly between different dimensions of IT use related to stages of implementation.	New dimensions were measured, such as: level of IT adoption (availability of IT), level of IT diffusion (functionality of IT, utilization of IT), etc.
Stage 5	Studies focused on IT use defined as IT diffusion: the extent to which it is used in organization to its fullest potential	In order to measure IT use in terms of IT diffusion questions about different activities it was used to support were asked.

With the growing number of information technologies becoming available for companies, numerous researchers realized that there is a need to extend the construct of IT use beyond the traditional dichotomous use/non-use variable or one-dimensional construct (Boynton *et al.*, 1994; Johannessen *et al.*, 1999). As Boynton *et al.* (1994) pointed out "while IT is used in many organizations, the extent to which it is applied creatively and to critical tasks varies widely". Johnannessen *et al.* (1999) further recommended "there is a need to consider what companies are using IT for and its consequences for innovation and performance". Already some of the early studies of IT use had recognized the need to address the aspect of what the information system is used for. The authors usually considered this aspect to represent one dimension of IT use along with other traditional dimensions, such as frequency of use and time. In order to capture it, different measures were proposed. The first studies addressing the aspect of what the IT is used for usually employed only single measure for this dimension. For example, Green and Hughes (1986) in their study of DSS use introduced measure *number of DSS features used.* Also Ginzberg (1981) used *number of functions used* as one of his dimensions of IT use, along with number of minutes and number of sessions. King and Rodriguez (1981) introduced measure *nature of queries.*

The next, third stage in developing IT use construct was related to further expanding the measure of 'the nature of IT use'. The new multidimensional construct, often referred to as the extent of IT use aimed at addressing different aspects of what IT was being used for. Numerous constructs were proposed, under different names: level of IT use, degree of IT use, IT utilization, progressive use of IT, IT penetration, IT adoption, IT assimilation. Many of these terms are overlapping or partially overlapping and there is no agreement on their definitions. For example, Vanlommel and DeBrabander (1975) proposed four levels of IT use: use for getting instructions, use for recording data, use for control, and use for planning. Schewe (1976) distinguished between two forms of IT use: general use of "routinely generated computer reports" and specific use of "personally initiated requests for additional information not ordinarily provided in routine reports", reflecting a higher level of system utilization. Ginzberg (1978) discussed the following three levels of IT use: use that results in management action, use that creates change, and recurring use of the system. Zmud *et al.* (1987) proposed four dimensions referring to what the IT system is being used for: use in support of cost reduction, management, strategy planning and competitive thrust. These and other definitions of IT use construct, together with the measurement tools are compared in Table 2.4.

The fourth stage in defining and measuring the construct of IT use was related to viewing IT as an innovation that has to be implemented in an organization and looking at the IT implementation models. Kwon and Zmud (1987) defined IT implementation as "an organizational effort directed toward diffusing appropriate information technology within a user community to support particular tasks within a specific work context" and developed one of the first IT implementation models. In this model they argued that IT implementation involves several stages: initiation, adoption, adaptation, acceptance, routinization, and infusion. The final product of IT implementation process is "the IT application used within the organization to its fullest potential" (Sullivan, 1985).

Introduction of IT implementation models made many researchers realize that although many IT innovations are widely acquired, they may only be partially deployed and this

Table 2.4 Definitions and empirical measures of IT use

Study	Construct and Its Definition	Measures
Alavi and Henderson (1981)	IT use seen as a one dimensional variable.	Use versus non use of computer-based decision aids
Ginzberg (1981)	No formal definition of IT use introduced, three dimensions included in the analysis.	Three measures of IT use: - number of minutes - number of sessions - number of functions used
Srinivasan (1985)	No formal definition of IT use introduced, three dimensions included in the analysis.	Three measures of IT use: - frequency of use - time per computer session - number of reports generated
Zmud *et al.* (1987)	**IT Penetration** The degree to which IT is "embedded within an organization's strategic, managerial, and operational work systems"	Respondents rated IT use in support of: - cost reduction - management - strategy planning - competitive thrust
Cooper and Zmud (1990)	IT adoption/IT usage is measured by the implementation of a technology's key features. IT infusion is related to importance, impact, or significance of the technology's features to company.	No empirical measures
Jarvenpaa and Ives (1991)	**Progressive Use of IT** Progressive use of IT (also referred to as strategic use of IT) implies that IT changes a firm's product or the way the firm competes in the industry.	Chief executive officers and IT managers rated their firms' current use of IT relative to competitors. The five point scale ranged from laggard to industry leader. The average of the responses constituted the measure of progressive use of IT within a firm.
Busch *et al.* (1991)	**Progressive Use of IT** Three dimensional construct defined by: the degree to which IT is used by the firm for strategic purposes, the technological sophistication of IT in the firm, and the relative positioning of the firm's use of IT in its industry.	Three items were measured: a) Use of IT compared to the industry b) Sophistication level of IT platforms c) Strategic nature of existing applications

Study	Construct and Its Definition	Measures
Boynton *et al.* (1994)	**IT Use** Defined as "the extent to which an organization deploys IT to support operational and strategic tasks" "IT use involves the extent to which IT takes the form of cost reduction, management support, strategic planning, and competitive thrust applications"	Respondents rated the use of each of four types of IT applications (cost reduction, management support, strategic planning and competitive thrust applications) on a five-point scale: (1) no use at all, (2) just starting, (3) used to some extent, (4) used to a great extent, and (5) "industry leader".
Vlahos and Ferratt (1995)	**Amount of IT Use** Defined as how often IT was used during employee's work.	Participants indicated the hours per week they used various types of hardware and software.
Johannessen *et al.* (1999)	**IT Use** Defined as the areas of company's activities where companies are using IT.	Respondents indicated on a five-point scale (1=completely disagree to 5=completely agree) the degree to which they had used IT in 13 areas: increased effectiveness, ease the work, develop new ways to manage the company, increase customer service quality, increase internal connectance, planning, decrease costs, differentiate service, change existing work processes, improve internal and external communication, increase access to market information, contribute to employees' access to common information foundation.
Corso and Paolucci (2001)	**ICT Utilization** Defined as the role of ICT in product innovation context. The authors distinguished between the utilization of ICT for storing and retrieving data, communicating data within organizational units and/or suppliers and customers, sustaining prototyping and analysis of innovative products.	In order to identify different patterns of ICT utilization the authors used four variables: 1) The role of ICT in product innovation 2) Investments in hardware and the degree of integration (stand alone PCs vs. networks) 3) Investments in software for product design and degree of integration among applications 4) Investments in tools aimed at storing and reusing design solutions

Study	Construct and Its Definition	Measures
Lee and Runge (2001)	**IT Adoption** IT adoption was defined as "the use of computer applications for business purpose". Hardware acquisition and standard office applications such as word processing and spreadsheets were excluded. Two constructs were considered: **information systems (IS) adoption** and **Internet adoption**.	The IS adoption was operationalized as the number of different types of information systems in use. Respondents were given a list of the systems commonly used by small business (accounting, inventory control, sales, purchasing, and personnel information systems) and were asked to check systems in use in their firm. The adoption of Internet technologies was operationalized as the number of Internet technologies in use by the firm. Choices were e-mail, home pages, electronic sales, and electronic purchase.
Lewis *et al.* (2004)	**IT Assimilation (Diffusion)** Assimilation of an IT is viewed as its acquisition and deployment in an organization context. **Acquisition of an IT** is defined as the extent to which the technology is made available to members of the organization (IT access/availability). **Deployment of an IT** is defined as the extent to which the technology is actually used by the members of the organization (IT utilization). Depending on the levels of IT acquisition and IT deployment, four IT assimilation levels were identified: limited, lagging, focused and pervasive assimilation.	The level of IT acquisition was measured for each of seven collaborative IT clusters considered in the study by a single item that required respondents to indicate to what extent the specific IT cluster was accessible and available to end-users in their organization to support task oriented collaboration. A five-point scale (1=no one in the organization, 3=some persons in the organization, and 5=everyone in the organization) was used. The utilization of an IT was measured by the extent to which an IT was being used by end-users in their organization to support task-oriented collaboration. A five-point scale using semantic anchors at the extremes and mid-way (1=never, 3=occasionally, and 5=always) was used for each of the seven IT clusters.
Del Aguila-Obra and Padilla-Meléndez (2006)	**Internet Technology Adoption** Six stages in the Internet technology adoption process: initiation, adoption, adaptation, acceptance, routinization, and infusion (based on Cooper and Zmud, 1990)	The authors used a number of factors to classify the respondent firms in different stages of Internet technology adoption. The factors included: the presence of outside consultants, the creation of a department and the use of the IS department to manage the Internet technology, managerial capabilities, and investment in own Internet technology.

fact needs to be addressed during defining and measuring the IT use construct. As a result, numerous studies on IT use started to distinguish between different dimensions of IT use related to the different stages and aspects of IT implementation/adoption. For example, Cooper and Zmud (1990) distinguished between two dimensions of IT use: *IT adoption* (implementation of a technology's key features) and *IT infusion* (the importance of the technology's features to the company). In a later study, Lewis *et al.* (2004) distinguished between the *IT acquisition* (i.e. its availability) and *IT deployment* (i.e. the actual extent of IT use or utilization).

In the last stage, numerous studies focused only on one aspect of IT use, reflecting the latest stage of IT implementation, i.e. the extent of IT use understood as "the extent to which the IT application is used within the organization to its fullest potential" (Cooper and Zmud, 1990). The authors who tried to address this aspect of IT use defined IT use as "the degree to which IT is used for strategic purposes" (Busch *et al.*, 1991), "the extent to which an organization deploys IT to support operational and strategic tasks" (Boynton *et al.*, 1994), "the use of computer applications for business purpose" (Lee and Runge, 2001). In order to measure IT use construct defined in this way, the researchers usually asked respondents to identify the areas of the company's activity where IT is used.

There are several important aspects of the definition of IT use which are highlighted in the literature. First of all, the literature agrees that the construct of IT use is multidimensional and besides what the IT is used for, there are also other dimensions such as: what technologies are used and what is their level of integration (this dimension became especially important when the technological development made numerous systems and applications available, see (Corso and Paolucci, 2001)), or who is using the IT technologies (different studies focus on different groups of respondents: managers, employees, direct users or indirect users, see (DeLone and McLean, 1992)).

The next finding from the literature on IT use is that while some empirical studies applied objective measures of IT use and therefore measured the *actual IT use*, other studies applied subjective measures and in fact measured the *reported or perceived IT use.* Empirical studies that measured the actual IT use introduced different objective measures such as: the number of computer enquires, amount of user connect time, the number of computer functions utilized, the number of client records processed, or the actual charges for computer use. Other studies have adopted a subjective (perceived) measure of use by questioning users about their use of an information system.

The last finding from the IT literature very relevant for the present study is the distinction among three concepts: IT adoption intentions, IT use, and benefits realized. Some authors fail to distinguish between them, for example Johannessen *et al.* (1999) measures IT use by asking respondents, among others, about the degree to which they had used IT to increase effectiveness or increase customer service quality. It is important to note that the intended benefits from IT implementation (such as for example cost reduction or improved communication) may not necessarily be achieved and their achievement may in fact depend to high degree on the different dimensions of IT use: who is using it, what technologies are being used, for what tasks, or how well they are integrated, etc.

The literature directly addressing the use of Internet-based technologies is not as well developed as the literature on IT use. Although it became widely recognized that the degree to which different companies get involved with Internet-based technologies varies significantly and that the results achieved through use of these technologies depend to large degree on the extent of their use, many empirical studies still simply consider it a binary variable 'used or not used', usually called the 'Internet adoption'. There are numerous studies comparing Internet adopters versus Internet non-adopters. Other studies deal with the issue of Internet-based technology use very artificially, by measuring it with indicators such as 'number of computer used'. For example, Lee and Runge (2001) operationalized the adoption of Internet-based technologies as the number of Internet-based technologies in use by the firm. In general it is visible that numerous authors investigating Internet-based technology use did not take advantage of the vast and well developed literature on IT use.

Very few studies explicitly define or measure the construct of Internet-based technology use during NPD project. An example of a research that did distinguish between different degrees of Internet-based technology use in NPD is work by Sethi *et al.* (2003). The authors pointed out that "an organization desiring to employ the web in its NPD process can use it at varying levels of functionality and sophistication, ranging from a tool for automating manual tasks and exchanging data to a means of integrating various intra- and interorganizational NPD functions and processes". Another framework of Internet-based technology use in NPD was proposed by Corso and Paolucci (2001). The authors discussed different introduction patterns of information and communication technologies (ICT) in NPD, but their framework is also applicable to Internet-based technologies. They proposed the following roles of ICT in product innovation (which can be considered different degrees of ICT use in NPD): ICT used for storing and retrieving data; ICT used for communicating data within organizational units; ICT used for communicating data with suppliers and customers; ICT used for sustaining prototyping and analysis of innovative products.

After reviewing the existing literature, the definition of Internet-based technology use in NPD project adopted in this thesis is based on the definition of IT use provided by Boynton *et al.* (1994). Therefore, Internet-based technology use in NPD project is defined as the extent to which the project team deploys Internet-based technologies to support NPD project activities and processes. Based on the review of the literature addressing the use of Internet-based technologies in NPD (which will be presented in the next section), in this thesis the use of Internet-based technologies is conceptualized as a four-dimensional construct encompassing: data and information management, collaborative team work, external partner/supplier/customer involvement and project management and control. Such a conceptualization reflects the wide variety of Internet-based technologies' applications across NPD projects in different industries, reflects that applications may be internally or externally focused, and recognizes that specific project teams might choose to emphasize particular types of applications given the nature of the project or their experience with Internet-based technology.

2.3.3 The Role of Internet-based Technologies in NPD Projects

With the emergence of the Internet and the recent developments in Internet-based technologies, a large number of studies dedicated to the Internet's specific use and role in new product development have been conducted. The consensus appears in the literature that due to its ease of use, wide availability, low cost, and common standards, the Internet has the potential to greatly improve NPD activities in many ways (e.g., Miller, 2001; Antonelli *et al.*, 2000).

In order to understand the role of Internet-based technologies in NPD, numerous authors studied companies that applied Internet-based technologies to their NPD activities. For example, Iansiti and MacCormack (1997) investigated how Netscape, Microsoft, and Fiat used the Internet to obtain inputs from internal and external customers of their products. Hameri and Nihtilä's (1997) study, on the other hand, mainly illustrated how the Internet can be used to exchange CAD files. A case study by Montoya-Weiss and O'Driscoll (2000) focused on how Northern Telecom used electronic performance support systems for structuring the new product idea development and evaluation process. Malhotra *et al.* (2001) addressed the issue of the Internet facilitating coordination and described how design engineers at Boeing-Rocketdyne used web applications to interact with their external design partners to redesign a rocket engine. Empirical studies (Avlonitis and Karayanni, 2000; Gessner *et al.*, 1994) have also shown that the Internet had been successfully used to support such product development activities as discovery of customer needs and product customization. These studies are providing valuable insights into the nature of Internet-based technology use and its potential role in supporting NPD activities; however, they are generally descriptive and focus only on selected aspects of NPD process.

It is widely recognized that the Internet-based technologies can be effectively implemented and used at various stages of the NPD process (Howe *et al.*, 2000; Farris *et al.*, 2003). Among numerous applications of Internet-based technologies in new product development, it was shown that they can be used in collecting competitive intelligence (Teo and Chow, 2001); testing new product prototypes (Dahan and Srinivasan, 2000); designing and manufacturing new products (Waurzyniak, 2001); creating new product awareness (Bickart and Schindler, 2001); securing new product funds (Kettlehut, 1991); communicating with experts around the world (Howe *et al.*, 2000); collecting immediate customer feedback (Mathieu, 1996); involving customers in the design process (Tuikka and Salmela, 1998), and conducting market research (Mathieu, 1996).

Internet-based technologies can also be used to support organizational learning and knowledge management, i.e. to collect, share and use high-quality information and competitive data needed for product development (Afuah, 2003; Bakos, 1997; Teo and

Chow, 2001; Hameri and Nihtilä, 1997; Ozer, 2000); to access databases for industrial research and development (Mathieu, 1996); to disseminate that information within the firm more efficiently; and to use it to make more informed decisions (Teo and Chow, 2001; Edwards *et al.*, 2005; Bennet and Tomblin, 2006). In the context of NPD, the Internet can further help firms to facilitate collaboration of different people who are involved in product development, to allow greater information exchange and foster greater participation in the NPD process, to achieve better access to knowledge residing in different parts of the firm, to locate suitable suppliers, to coordinate the NPD activities, and to involve more participants in the process (Ozer, 2003). It can also help firms document their resources better (Kehoe and Boughton, 2001). An example of a web-based XML information sharing system designed to support distributed collaborative product development activities has recently been proposed by Tsai, Sun and Huang (2006). The authors argue that the proposed method allows designers to be more productive and innovative through seamless information sharing and exchange.

Internet-based technologies can enhance the integration and coordination of NPD activities by allowing employees in different departments within the firm to share information, by enabling firms to exchange ideas with firms in their value chains and by helping them communicate with their customers better (Afuah, 2003; Hameri and Nihtilä, 1997; Ozer, 2003). Firms can take advantage of numerous Internet-based technologies in their NPD process, including computer-aided design (CAD) and computer-aided manufacturing (CAM), to leverage their technical strengths. The Internet enables companies to be more efficient by allowing them to conduct virtual prototype testing without actually developing a prototype (Dahan and Srinivasan, 2000). Ozer (2000) argues that the Internet can also enable companies to enhance the manufacturability of their new products by taking advantage of the expertise of people located in different parts of the world. The Internet can also be used to conduct market research and promote new products (McMellon and Schiffman, 2001); and thus can play very important role in allowing companies to launch their new products in remote locations more effectively and efficiently or even enable them to sell their products in global markets that otherwise would be impossible for them to reach (Hamill, 1997; Yeoh, 2000).

Use of the Internet can help companies to make better decisions with regard to product line planning, to understand the market better and thus target it more efficiently, to formulate and implement new product strategies faster, to generate a wide range of new product ideas, to generate ideas from a wide range of sources, to make the concept screening process more objective, comprehensive and flexible, to increase speed and quality of business analysis (Ozer, 2003), to receive immediate customer feedback (Mathieu, 1996), to conduct virtual prototype tests, to conduct remote product simulations, and to exchange images in real time (Ozer, 2003). The Internet can also play significant role in facilitating information dissemination (Howe *et al.*, 2000). Ghosh (1998) in more detail discussed potential ways for a company to use the Internet to develop and deliver new products and services for new customers. These ways included using the Internet for direct access to customers (marketing), for serving new customer segments (new niches), and for conducting transactions (e-commerce).

In general, it has been hypothesized that use of Internet-based technologies in product development can lead to performance benefits in terms of cost reduction (Howe *et al.*, 2000), improvement of process (Howe *et al.*, 2000), and shortening the development cycle of new products (Howe *et al.*, 2000; Mathieu, 1996). All these potential benefits of Internet-based technologies encourage companies to invest in them. As more sophisticated or integrated NPD software packages are entering the market, firms are increasingly eager to adopt systems for integrating various NPD activities (Sethi *et al.*, 2003).

However, the research on the impact of information technology on organization in general, as well as the research on the impact of the Internet on new product development in particular, agrees that although implementation of technology itself creates opportunity for significant performance improvement, it is not a sufficient condition of achieving this improvement. First, it is important what technology is adopted and for what activities. Second, as Corso and Paolucci (2001) pointed out, adoption of IT in isolation from the organizational and managerial context is not adequate to exploit all the potential benefits deriving from the use of it. As a result, lack of performance improvement after implementation of information technologies is not, in many cases, due to technical reasons, but rather to a lack of proper organizational and managerial context.

2.3.4 Theoretical Frameworks

Existing research examining the relationship between the extent of the Internet use and NPD performance is sparse. Five key studies proposing a theoretical basis for understanding the role of the Internet in new product development have been identified. These studies (Ozer, 2003; 2004; Kessler, 2003; Sethi *et al.*, 2003; Pavlou and El Sawy, 2006) provide the foundation for this research.

Ozer (2003; 2004)

In his first article, Ozer (2003) developed theoretical model of the Internet's role in the different stages of the NPD process. He distinguished among nine NPD stages and identified the following benefits offered by the Internet at each stage:

- *At product line planning stage* the Internet can help firms collect, categorize and use information needed for product line planning and it can lead firms to make better decisions with regard to product planning,
- *At strategy development stage* the Internet can help companies understand their market better and thus target it more efficiently and it can help formulate and implement new product strategies faster,
- *At the concept generation stage* the Internet can help generate a wide range of new product ideas and it can generate ideas from a wide range of sources,
- *At the concept screening stage* the Internet can enhance the comprehensiveness and flexibility of the concept screening process and make it more objective,

- *At the business analysis stage* the Internet can increase the speed and quality of business analysis,
- *At the development stage* the Internet can facilitate the collaboration among the new product development team members and it can improve the operational performance of new product development activities,
- *At the testing and validation stage* the Internet can significantly increase the speed and quality and decrease the cost of testing and validation,
- *At the manufacturing development stage* the Internet can increase the quality and the efficiency of manufacturing development,
- *At the commercialization stage* the Internet can increase the efficiency and enhance the success of new product commercialization.

In his follow-up study, Ozer (2004) proposed a model of the role of the Internet in new product performance, see Figure 2.3. Despite its unquestionable merits, his study lacks the concept of Internet-based technology use, i.e. it does not address the issue of different levels or patterns of Internet-based technologies use. Also, it is not clear whether the author is only investigating the Internet or also other Internet-based technologies and how he distinguishes among them. His model, presented in Figure 2.3, provides a framework of four main types of the Internet impact on new product performance, however, it is not based on theoretical literature and also there is confusion between the middle part of the model and definition of product performance.

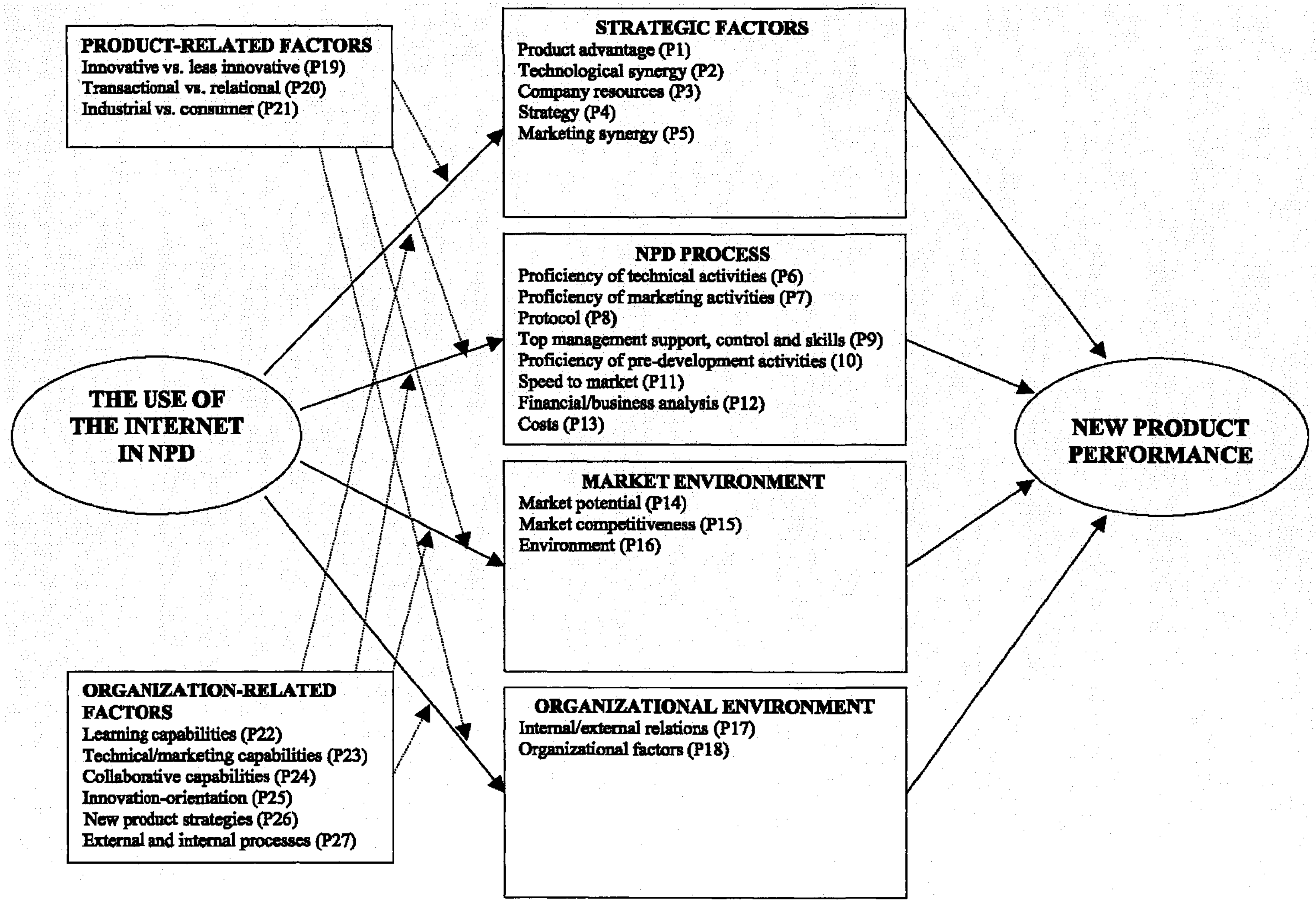


Figure 2.3 The role of the Internet in new product performance
Source: (Ozer, 2004)

Kessler (2003)

Kessler (2003) proposed a knowledge-based framework for understanding and testing the effects of Internet technology application on the R&D team processes and their outcomes. Important theoretical contribution of his research is the recognition that the internal and external learning processes of the NPD team (involving creation of knowledge by individuals, its transfer and application to the new product) play very important role in contributing to NPD performance. Based on this observation, he hypothesized that "organizations that leverage e-R&D networks in project groups' internal and external learning processes to a greater extent will be more successful innovators than those organizations that do so to a lesser extent". Although it is a very important hypothesis, Kessler (2003) did not specify how exactly the Internet-based technologies affect the outcomes of the NPD process (i.e. did not define his understanding of 'successful innovator') and did not test it empirically. In this thesis it is hypothesized more explicitly that the use of Internet-based technologies leads to the improvement of the effectiveness of team learning and through it to the improvement of NPD performance.

Another significant contribution made by Kessler (2003) is the 3D e-R&D model that can be used to examine the effects of the Internet application (segmented by its different attributes or functionalities) on the R&D process (segmented by its different stages or sets of related activities) and on the R&D outcome (segmented by its different dimensions or strategic variables), see Figure 2.4. The first dimension of the proposed model is the Internet application. The author considers the following four general categories of Internet functions (based on Leshin, 1997): communication, connection, transfer, and access. The second dimension of the e-R&D model is R&D process. The author examined three NPD process stages: pre-development, initiation and implementation. Finally, the third dimension is R&D outcome, including: process speed, project efficiency, and product quality.

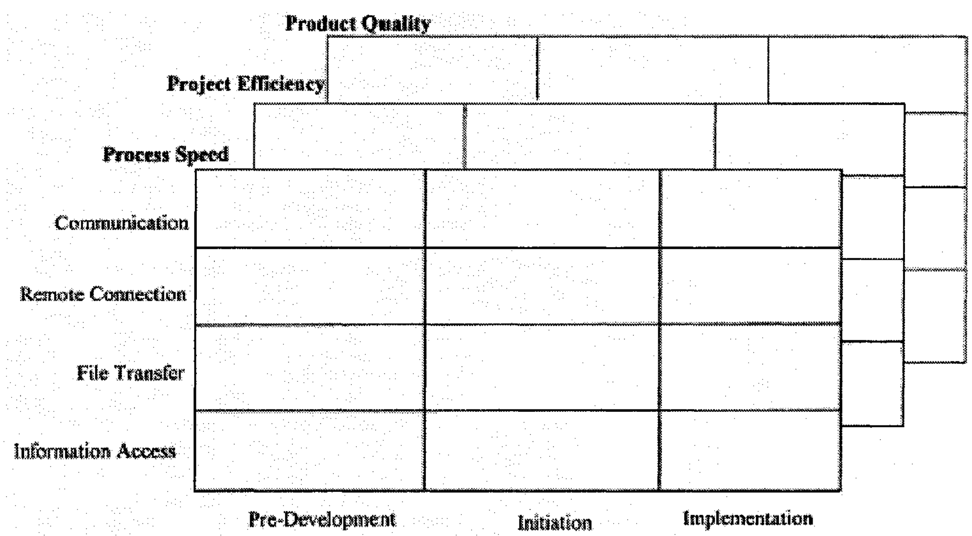


Figure 2.4 3D e-R&D Model
Source: (Kessler, 2003)

Kessler (2003) pointed out that some functions of Internet technologies may be better able to facilitate one stage of NPD than other and impact one outcome more than other. To this respect he formulated several hypotheses, directly pointing to the fact that the Internet's impact on NPD depends to large degree on the nature of the Internet functions and their richness, i.e. on the extent of the Internet use as understood in this thesis. He hypothesized that although the Internet has the potential to positively affect all stages and all outcomes of the R&D process, its impact will differ depending on: the nature of its use (richer functions of the Internet will have a greater effect on the outcomes of the R&D process), the fit between the characteristics of the Internet function and the demands of the outcome and on the fit between the richness of the Internet function and the information intensity and networked communication requirements of the NPD stage. Although Kessler (2003) made valid observations, he did not test his model empirically.

Sethi, Pant and Sethi (2003)

In their article, Sethi, Pant and Sethi (2003) developed a conceptual framework focused on how Internet-based NPD system integration affects the outcome of NPD activity and how this relationship can be influenced by various contextual factors, see Figure 2.5.

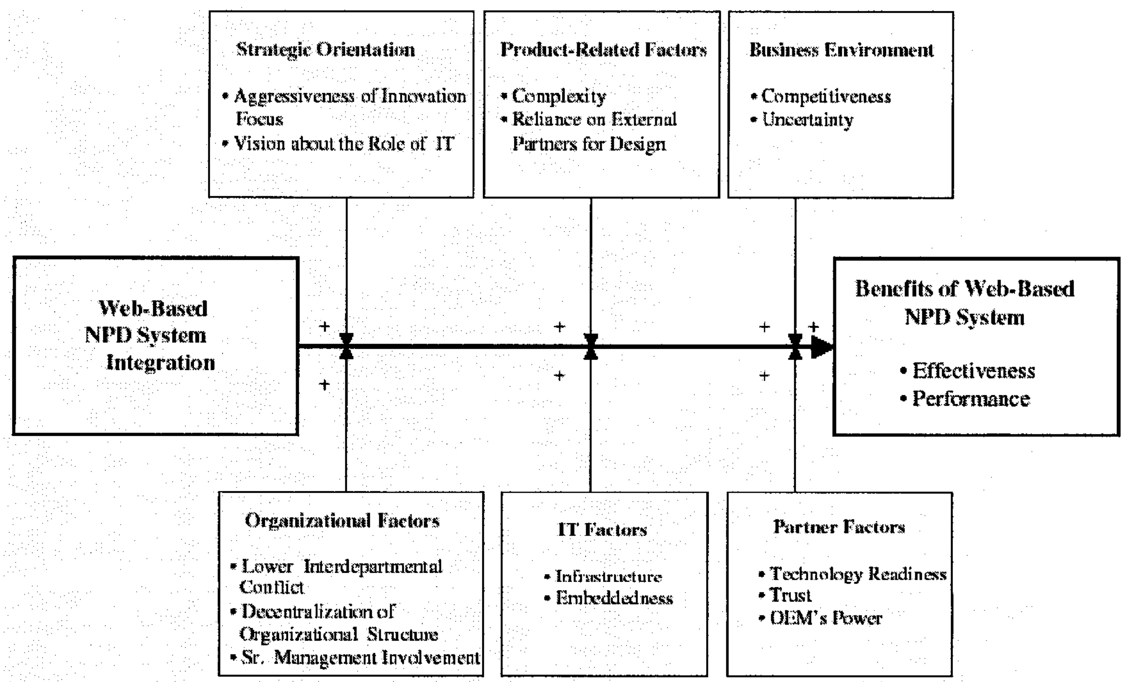


Figure 2.5 Internet-based NPD system integration and new product outcomes
Source: (Sethi *et al.*, 2003)

There are several important contributions made in their paper. First of all, the authors stressed the fact that organizations can use Internet technologies at varying levels of functionality and sophistication, ranging from a tool for automating manual tasks and exchanging data to a means of integrating various intra- and interorganizational NPD functions and processes. They further argued that different levels of use of Internet technologies lead to different degrees of internal and external integration of NPD process and have different impact on NPD outcome. Although integration is considered important for NPD performance, Sethi et al. (2003) pointed out that decision makers considering implementation of Internet-based solutions in NPD should realize that more sophisticated solutions are related to higher costs of technology, higher costs of implementing the system and higher costs of redesigning the existing processes.

In order to address the need to recognize different levels of Internet-based technology use, the authors introduced construct of 'web-based NPD systems integration' defined as "how extensively computer systems are used in various NPD processes and the degree to which these systems are interlinked through the Web and interoperate (sic) with one another". They further identified four levels of web-based NPD systems integration: namely transactional, intrastage, interstage and extended, which represent increasing levels of information technology sophistication for web-based NPD. They argued that each successive level of sophistication consists of all the features and capabilities of the previous level and more. Transactional integration involves facilitating and speeding up interactions (exchange of messages and files) among functional areas involved in NPD.

Intrastage integration entails using web-based systems to integrate processes within a given stage of NPD process and to integrate different databases within this stage. Interstage integration adds the integration of processes and databases between the stages. Finally, the last and the highest level of technology sophistication means that NPD processes and databases of an organization are integrated with those of external partners and major customers. Despite the merits of this approach, the authors seem to make too strong assumption regarding the fact that each of the levels encompasses the features of the previous levels. For example, their model does not include NPD projects characterized by a high level of integration between R&D department of the company developing the product and one of its suppliers (co-development approach) and at the same time lacking strong integration between the same R&D department and the marketing department.

The second very important contribution to the understanding of the Internet's role in NPD made by Sethi et al. (2003) is the identification of the contextual factors affecting the relationship between the Internet use and NPD outcomes. The authors argued that if the Internet-based systems are installed without appropriate conditions within and outside the firm, the company may not be able to exploit their full potential. The 14 contextual factors identified in their study are grouped as follows: strategic orientation of the firm factors (aggressiveness of innovation focus, vision about the role of IT), product-related factors (complexity, reliance on external partners for design), business environment factors (competitiveness, uncertainty), organizational factors (lower interdepartmental conflict, decentralization of organizational structure, senior management involvement), information technology factors (infrastructure, embeddedness) and partner-related factors (technology readiness, trust, power). Although the proposed framework is well grounded in the literature and provides a very comprehensive picture of the relationship between Internet-based technologies and NPD outcomes, it has not yet been tested empirically.

Pavlou and El Sawy (2006)

The study conducted by Pavlou and El Sawy (2006) focused on answering the question whether and how IT can build competitive advantage in turbulent environments. Although this study did not investigate the role of the Internet, but IT in general, its findings are still reported here, because of their value for better understanding of the role of the IT, and the Internet in particular, in NPD. The authors introduced the construct of *IT leveraging competence* – the ability to effectively use IT functionalities. This construct was then conceptualized in the context of new product development. IT leveraging competence is shown to indirectly influence competitive advantage in NPD through two key mediating links: *functional competencies* (the ability to effectively execute operational NPD processes) and *dynamic capabilities* (the ability to reconfigure functional competencies to address turbulent environments).

2.4 Conclusions

In the early research, it was of interest to investigate only whether the Internet was used or was not used by a firm. Newer studies recognize that the benefits and the role of the

Internet in NPD depends to large degree on the extent of its use (Kessler, 2003; Sethi *et al.*, 2003). The researchers are concerned that most firms are still not exploiting the potential of the Internet in their NPD activities (Miller, 2001). The existing literature on the Internet's role in new product development is very rich in case studies and theoretical prepositions regarding potential benefits of the Internet. However, it is at the same time not well structured and confusing. In many research papers there is no clear definition of the Internet technology use or there is no clear distinction among the Internet adoption intentions, the Internet use and the benefits realized through the Internet use. There has been comparatively little conceptual modeling, especially with regard to building comprehensive framework of the Internet's role in NPD and relationship between its use and NPD performance. There is also lack of systematic, empirical investigation into the optimization of the use of the Internet in NPD context. Although there is a general acknowledgement in the literature that Internet-based technologies are potentially valuable tools to facilitate and improve NPD process, there are few specific, empirical studies testing this assertion. Rather, most of the articles are based on case studies. Also, the articles in this field are largely disconnected from each other. Although the existing theoretical research and case studies are no doubt useful, they do not fully answer the needs of practitioners who would like to know what level of sophistication or integration in web-based NPD systems is appropriate for their NPD activities.

CHAPTER 3

THEORETICAL FRAMEWORK

This chapter describes the research model proposed in this study. First, the research questions are stated, and then the model, resulting from the existing literature, is described and presented in Figure 3.1. Each of the model's constructs is defined, measures are presented, and all hypothesized relationships are discussed.

3.1 Introduction

The literature summarized and presented in Chapter 2 indicates that there is a significant and increasing trend towards implementation of Internet-based technologies in NPD projects aimed at improving NPD performance (e.g., Miller, 2001; Antonelli *et al.*, 2000; Iansiti and MacCormack, 1997; Malhotra *et al.*, 2001; Dahan and Srinivasan, 2000; Sethi *et al.*, 2003). Some researchers and practitioners even claim that adoption of Internet-based technologies not only creates opportunities for the improvement of NPD performance, but is simply becoming necessary condition of successful product development (e.g., Corso and Paolucci, 2001).

However, at the same time, numerous companies who invested in Internet-based technologies hoping to achieve better results in their new product development activities, did not gain the expected benefits. After reviewing the experiences of companies involved in Internet-based tools for NPD, Corso and Paolucci (2001) concluded that despite their alleged role in supporting the process of new product development, these new applications are still offering uncertain returns and have ambiguous effects on firms' innovative capabilities.

The existing research does not offer sufficient explanation of why investments in Internet-based tools for NPD do not always bring improvement in performance. In general, there is a lack of deeper understanding of the relationship between the nature of Internet-based technology use and NPD performance. Therefore, there is very little systematic guidance offered to companies to help them decide which technologies are suitable for their NPD activities and how these technologies should be applied and used to bring the most benefits. Despite numerous claims in the literature that Internet-based technologies can lead to more efficient and effective new product development, there is still lack of systematic, empirical studies supporting this view. Therefore, the objective of this study is to contribute to a better understanding of the relationship between Internet-based technologies and NPD performance and to provide empirical evidence that would help answer the question about this relationship.

3.2 Research Question

The central focus of this study is the alleged improvement of NPD performance that could be achieved through the use of Internet-based technologies in different areas of NPD activity. The research question is therefore stated as follows:

What is the impact of the use of Internet-based technologies on new product development performance and what contextual factors moderate this relationship?

In order to answer the above research question, several issues necessary for a better understanding of the potential role of Internet-based technologies in product development have to be first explored. First of all, the nature of the use of Internet-based technologies during the NPD project will be researched. Then, the impact of the use of Internet-based technologies on NPD performance will be investigated. Since it is hypothesized that this impact is not direct, but takes place through two channels, namely team integration and effectiveness of team learning, the mediator roles of these variables will be investigated. Special attention will be paid to the central role of communication quality. Finally, the moderating role of environment uncertainty, product characteristics and project team characteristics will be investigated in order to identify the conditions under which the impact of Internet-based technologies on project performance may be more pronounced. Therefore, the research question presented above is broken into the following investigative questions:

1. What is the extent of the use of Internet-based technologies during new product development projects?
2. What is the impact, if any, of the use of Internet-based technologies in NPD project on project team communication quality, team integration, and effectiveness of team learning?
3. What is the impact of team integration and effectiveness of team learning on NPD performance?

4. How does the relationship between the use of Internet-based technologies during NPD project and NPD performance change across different levels of environment uncertainty, product characteristics, and project team characteristics?

In order to answer the research questions stated above, a model of the impact of the use of Internet-based technologies on NPD performance was developed based on the literature review summarized in Chapter 2.

3.3 Research Model

The model outlining the proposed relationships between the use of Internet-based technologies and NPD performance is presented in Figure 3.1 and consists of four blocks: the use of Internet-based technologies in NPD project; NPD performance; intervening variables, i.e. communication quality, team integration, and effectiveness of team learning; and moderating variables (environmental uncertainty, product innovativeness, product complexity, technology novelty, team functional diversity, team proximity, team stability, and team size). These parts are joined by causal relationships that are supported by earlier research in the innovation and organizational theory fields.

This research proposes that the use of Internet-based technologies during the execution of NPD project leads to the improvement of team communication quality, team integration and effectiveness of team learning. The impact of Internet-based technologies on team integration and effectiveness of team learning is hypothesized to be both direct and indirect, achieved through the improvement of team communication quality. Next, it is stated that team integration and effectiveness of team learning lead to the improvement of NPD performance. Therefore, the impact of Internet-based technologies on NPD performance is not direct, but takes place through two complimentary channels: through the improvement of team integration, and the improvement of effectiveness of team learning. The strength of these relationships depends on the following factors: *environmental uncertainty*, *product characteristics* (product innovativeness, product complexity, and technology novelty); and *project team characteristics* (team functional diversity, team proximity, team stability, and team size).

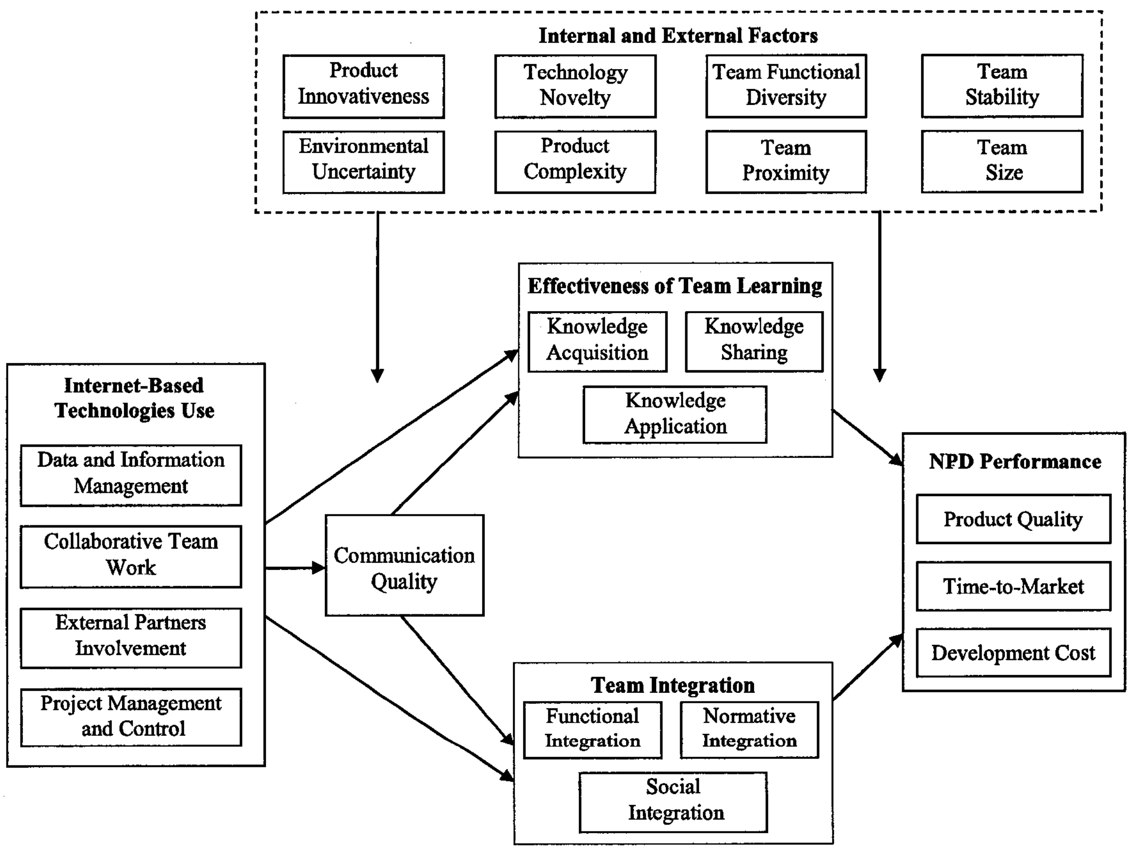


Figure 3.1 Model of the impact of IBT use on NPD performance

The remainder of this chapter discusses the model, beginning with the description of NPD performance and its direct determinants, followed by the description of the use of Internet-based technologies in NPD and a discussion of contextual factors. All the constructs are defined, their measures are introduced, and the hypotheses are formulated and discussed.

3.3.1 NPD Performance

As previously stated, based on the literature review, it is expected that the use of Internet-based technologies during an NPD project will positively influence the project performance. This research focuses on NPD performance viewed as internal (project) performance, and does not address external (market) performance as defined by Hauptman and Hirji (1996) or Tatikonda and Rosenthal (2000). Following numerous studies in the innovation field (Clark and Fujimoto, 1991; Emmanuelides, 1993; Doz, 1996; Neely *et al.*, 1995; Danneels and Kleinschmidt, 2001; Garcia and Calantone, 2002) this research views NPD performance as a multidimensional construct, consisting of one product-oriented dimension (product quality) and two process-oriented dimensions (time-to-market and development cost). Internal NPD performance is of interest for companies, because it can lead to improved chances of new product market success (i.e. competitive position, market share, financial returns, etc.). However, since numerous past researchers have empirically shown that all three dimensions of NPD performance considered in this study are significantly correlated with new product success (for a review of these studies see for example work by Ernst (2002)), retesting of these relationships is outside the scope of this study.

Since this thesis investigates the role of Internet-based technology use during NPD project execution, it is appropriate to measure NPD performance on the level of an individual project. The examples of how to conceptualize and measure NPD performance on the project-level presented and recommended in the innovation literature have two common characteristics. First, the recommended measures are subjective, based on evaluations by project managers or project staff (Tatikonda and Rosenthal, 2000) and, second, these measures are anchored around meeting specific project goals (Hauptman and Hirji, 1996).

3.3.1.1 Product Quality

In this thesis product quality is defined as the degree to which product performance, attributes, or features satisfy customer requirements (Gitlow and Gitlow, 1987; Juran and Gyrna, 1988; Clark and Fujimoto, 1991; Deschamps and Nayak, 1995; Gehani, 1993; Kessler and Chakrabarti, 1998). Following the approach proposed by Kessler and Chakrabarti (1998), product quality was measured in three ways, which mirrored the measurement of time-to-market and development cost, i.e., relative to budget, similar past projects, and similar competitor projects. The items were:

1. Please rate your product quality as compared to quality goals at the start of the project.

2. Please rate your product quality as compared to quality of similar past products in your organization.
3. Please rate your product quality as compared to quality of similar competitor products.

Items were measured using a 5-point Likert scale where 1 = significantly inferior; 3 = about the same; and 5 = significantly superior.

3.3.1.2 Time-to-Market

Time-to-market represents the first process-oriented dimension of NPD performance considered in this thesis and is defined as the time elapsed between the preliminary assessment of an already approved idea and the ultimate commercialization, which is the introduction of a new product into the marketplace (Mansfield, 1988; Murmann, 1994; Vesey, 1991; Clark and Fujimoto, 1991). In other words it is the time taken by a team to develop and launch a new product (Olson *et al.*, 1995; Sarin and Mahajan, 2001; Sarin and McDermott, 2003). Time-to-market was operationalized through three relative measures: (a) time relative to schedule or 'on-time performance' (McDonough, 1993; McDonough and Barczak, 1991), (b) time relative to similar, previously completed projects in one's organization, or 'acceleration' (e.g., Crawford, 1992; Graves, 1989; Gupta and Wilemon, 1990; Millson et al., 1992; Nijissen et al., 1995; Sarin and Mahajan, 2001), and (c) time relative to similar projects of competitors, or 'competitive speed' (e.g., Stalk and Hout, 1990; Vesey, 1991; Olson *et al.*, 1995). The final measurement tool for time-to-market was based on the work by Kessler and Chakrabarti (1998) and Sarin and McDermott (2003) and included the following three items:

1. Please rate the time taken to develop and launch this product as compared to time expected at the start of the project.
2. Please rate the time taken to develop and launch this product as compared to time taken to develop and launch similar products in your organization in the past.
3. Please rate the time taken to develop and launch this product as compared to time taken to develop and launch similar products by your nearest competitors.

Items were measured using a 5-point Likert scale where 1 = much longer; 3 = about the same; and 5 = much shorter.

3.3.1.3 <u>Development Cost</u>

Development cost is the second process-oriented dimension of NPD performance considered in this thesis and is defined as the total financial requirements and associated human resources needed to complete the project (Rosenthal, 1992). Development cost was also measured with three items, which mirrored the measurement of time-to-market, i.e., it was measured relative to (a) budget, (b) similar past projects, and (c) similar competitor projects. This approach has already been proposed and applied in numerous previous studies in innovation field (e.g., Kessler and Chakrabarti, 1998; Kessler *et al.*, 2000). The measurement items for the development cost used in this thesis included therefore the following three items:

1. Please rate the total project cost as compared to the budget goal.
2. Please rate the total project cost as compared to the total cost of similar past projects in your organization.
3. Please rate the total project cost as compared to the total cost of similar projects executed by your nearest competitors.

Items were measured using a 5-point Likert scale where 1 = much higher; 3 = about the same; and 5 = much lower.

3.3.2 Team Integration

The definition of team integration adopted in this thesis is based on work by Lawrence and Lorsch (1967b) and states that team integration is "the degree of unity of efforts among team members in the accomplishment of the project's goal". After Feldman (1968) the construct of team integration is conceptualized in this thesis as having three dimensions: functional integration, normative integration, and social integration.

3.3.2.1 Functional Integration

Functional integration is defined as "the degree of coordination of group members' activities required to progress towards the goal" (Feldman, 1968) and addresses issues such as timing, sequence, and synchronization of interdependent tasks, resource allocation, and task assignment (Ettlie, 1997; Swink, 1999; Malone and Crowston, 1994; Crowston and Kammerer, 1998; Marks *et al.*, 2001). It can be viewed as the degree of success in managing dependencies among activities (Malone and Crowston, 1994). For the purpose of this study the measurement tool for functional integration was developed based on the work by Mohr and Spekman (1994), Malone and Crowston (1994) and Crowston and Kammerer (1998). Respondents were asked to indicate the extent to which they agree with the following statements:

1. Activities performed by different project team members were well coordinated.
2. The resources were allocated within the team effectively.
3. Project team members were assigned to tasks matching their knowledge and skills.

Items were measured using a 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree.

3.3.2.2 Normative Integration

Normative integration is defined as "the degree of consensus among group members concerning a number of group-relevant behaviours and norms" (Feldman, 1968). It was measured with measurement items based on the approach proposed by Kahn and Mentzer (1996) and Koufteros *et al.* (2005). Respondents were asked to indicate the extent to which they agree with the following statements:

1. Project team members had common vision and goals.
2. Project team members shared resources to complete tasks.
3. Project team members achieved goals collectively.
4. Project team members worked together as a team.
5. Project team members sought integrative solutions.

Items were measured using a 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree.

3.3.2.3 *Social Integration*

Social integration is defined as "the cohesiveness of the group i.e., the reciprocal liking and attraction among group members" (Feldman, 1968; Scott, 1997). It is primarily affective in nature and develops through the relationships among team members (Lott and Lott, 1965; Shaw, 1971; O'Reilly *et al.*, 1991). A measurement scale developed by Seashore (1954) and later applied and modified by numerous other researchers (e.g., Ancona and Caldwell, 1992b; Scott, 1997), was used in this study to measure social integration within project team. The respondents were asked to rate the extent to which they agree with the following statements:

1. Project team members recognized each other's talents and expertise.
2. Project team members were likely to defend each other from criticism by outsiders.
3. Project team members helped each other to more effectively perform their tasks.
4. Project team members got along well with each other.
5. Project team members perceived their problems as mutual problems.

Items were measured using a 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree.

Team integration or its particular aspects have repeatedly been found important contributors to different dimensions of NPD performance (e.g., Cooper, 1983; Gupta *et al.*, 1985; Gupta *et al.*, 1986; Keller, 1986; Griffin and Hauser, 1996; Kahn, 1996; Moenaert *et al.*, 1994; Scott, 1997; Souder and Moenaert, 1992; Droge *et al.*, 2000;

Sherman *et al.*, 2000; Swink and Song, 2007) as well as to the overall project success (Cooper, 1983, 1984; Hise *et al.*, 1990; Song and Parry, 1992; Souder, 1987, 1988; Souder *et al.*, 1997; Souder and Chakrabarti, 1978; Swink and Song, 2007). Despite the empirical confirmation of the positive impact of team integration on NPD performance this relationship was retested in this thesis. There are at least two important benefits of doing it. First of all, the previous studies investigating the impact of team integration on NPD performance used very different definitions and conceptualizations of team integration and were conducted in very different contexts. None of them applied the conceptualization of team integration as it is adopted in this study. Therefore, based on the existing research it is difficult to conclude with certainty that in the settings of the present study team integration will positively affect NPD performance and testing this relationship no doubt adds value to the research.

Secondly, testing the strength of the relationship between team integration and NPD performance is a necessary prerequisite to further analysis of the nature of the impact of Internet-based technology use on NPD performance. Without testing the relationship between team integration and NPD performance in the context of the present study, it would be impossible to verify whether the use of Internet-based technologies affects NPD performance indirectly through the improvement of team integration. Therefore, the following hypothesis is forwarded:

Hypothesis 1 Project team integration will positively influence NPD performance.

3.3.3 Effectiveness of Team Learning

Team learning is defined as collective activity, performed by team members, of information/knowledge acquisition, knowledge sharing, and knowledge application during the execution of a project in order to achieve the common goal of the project team (Nonaka and Takeuchi, 1995; Grant, 1996b; Meyers and Wilemon, 1989; Edmondson, 1999). Teams learn either by acquiring pre-existing information, or by developing new knowledge through trial and error (Huber, 1991; Cohen and Levinthal, 1990). Following the earlier research, team learning in this study is conceptualized as a three dimensional construct consisting of information acquisition, knowledge sharing, and knowledge application.

3.3.3.1 *Information Acquisition*

Effectiveness of information acquisition is defined as the effectiveness of the process of acquiring and storing relevant information for product development. In order to measure the information acquisition effectiveness, the measurement tools developed by Akgün *et al.* (2002) and Brockman and Morgan (2003) were adapted and respondents were asked to rate the extent to which they agree with the following statements:

1. The project team displayed a high level of competence in acquiring the information needed to develop the product.
2. The project team acquired the information needed to develop the product from a variety of sources.
3. The project team gathered sufficient relevant internal and external information regarding customers, markets, technologies, and competitors during the project.

4. The project team organized and stored the information generated during the process in a meaningful way.

Items were measured using a 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree.

3.3.3.2 *Knowledge Sharing*

Effectiveness of knowledge sharing is defined as the effectiveness of the process of information sharing and interpretation and is expressed by the level of shared understanding, i.e. consensus on the meaning of the information and its implication for the project (Brockman and Morgan, 2003). Information sharing refers to the extent to which critical, often proprietary, information is communicated to other team members (Mohr and Spekman, 1994). Effective information sharing is considered to allow teams to complete their tasks more efficiently and to lead to partnership success (Devlin and Bleackley, 1988).

During NPD project execution, sharing of information and knowledge takes place across functions, across the phases of the process, across geographic boundaries if the project is conducted in multiple sites, and across organizations (Adams *et al.*, 1998). It can be performed formally, through structured means such as database policies, presentations, memos, meetings and other cross-functional efforts, or informally through interpersonal interactions and team educational efforts. Knowledge sharing is very important, because information is useful only to the extent that it is shared quickly and efficiently with all the relevant users (Adams *et al.*, 1998). For the purpose of this thesis, the effectiveness of knowledge sharing was measured with modified measurement items developed by Brockman and Morgan (2003) and Akgün *et al.* (2002). Respondents were asked to indicate the extent to which they agree with the following statements:

1. The project team was successful at distributing information needed for task completion among the team members.
2. Project team members were well aware of where specialized knowledge is located and needed in the project.
3. Project team members had good insight of what everybody else involved with this project was doing.
4. Project team members developed a similar understanding of the role the acquired information would play in developing the product.
5. Project team members openly shared their ideas with each other.

Items were measured using a 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree.

3.3.3.3 Knowledge Application

Effectiveness of knowledge application is defined as the effectiveness of the process of information utilization for decision making and problem solving. In order to measure effectiveness of knowledge application, the approach developed by Akgün *et al.* (2002) and Akgün *et al.* (2006) was adapted. Respondents were asked to indicate the extent to which they agree with the following statements:

1. During the project, the product development process improved.

2. The project team had the ability to incorporate lessons learned during the project into the final product.
3. The project team had the ability to translate customer needs into product design specifications.
4. The project team was able to effectively respond to changes in customer needs.
5. The project team was able to effectively respond to changes in technological environment.
6. The project team was very good at joint problem solving.

Items were measured using a 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree.

Previous studies have shown that team learning positively influences performance of teams in organizations (e.g., Arrow, 1962; Nelson and Winter, 1982; Fiol and Lyles, 1985; Edmondson, 1999; Cohen and Levinthal, 1990; Sarin and McDermott, 2003). For example, Sarin and McDermott (2003) using data from a study of 52 NPD projects, demonstrated that project team learning has a strong positive effect on development time of new products. McKee (1992) and Mishra *et al.* (1996) argued that team learning increases the effectiveness of product development efforts as a result of practice and the refinement of innovation-related skills. With experience, team members become more proficient at acquiring, sharing, processing, and applying information (Sarin and McDermott, 2003), in turn making fewer mistakes and quicker decisions. Therefore, it can be expected that team learning is likely to improve all the three dimensions of NPD performance considered in this study, i.e. product quality, time-to-market, and development cost.

Similarly as with project team integration, despite the vast amount of empirical research on the relationship between team learning and NPD performance, this relationship will be investigated in this study as well. The reasons are as follow. The existing research is not consistent in terms of definitions, conceptualization, and measurement of team learning, and particularly there is no research addressing the effectiveness of team learning as it is introduced and investigated in this thesis. Second, evaluation of the relationship between effectiveness of team learning and project performance will enable further analysis of the indirect effect of the use of Internet-based technologies on NPD performance. Therefore, the following hypothesis is advanced:

Hypothesis 2 Effectiveness of project team learning will positively influence NPD performance.

3.3.4 Communication Quality

Communication quality during the execution of a development project is defined as the degree to which relevant and understandable information reaches the intended information receivers in time (Lievens and Moenaert, 2001; Moenaert *et al.*, 2000). In order to measure team communication quality for the purpose of this thesis, the measurement tool developed by Mohr and Spekman (1994) was extended. Accordingly, communication quality was measured by the extent to which respondents agreed with the following statements:

1. Communication among team members was timely.

2. Communication among team members was reliable.
3. Communication among team members was open.
4. Communication among team members was accurate.
5. Communication among team members was effective.

Items were measured using a 5-point Likert scale where 1 = strongly disagree and 5 = strongly agree.

The importance of communication in new product development has been repeatedly postulated in the literature on innovation (Allen, 1985; Rogers and Shoemaker, 1971; Rogers and Agarwala-Rogers, 1976). Since communication provides a means for the exchange of information among team members and between team members and their environment (Pinto and Pinto, 1990), it can be expected that it has a positive impact on effectiveness of team learning and level of team integration. In this thesis, it is therefore hypothesized that communication quality positively affects effectiveness of team learning and team integration, and through them indirectly affects NPD performance. Therefore, the following hypotheses are proposed:

Hypothesis 3 Project team communication quality will positively influence project team integration.

Hypothesis 4 Project team communication quality will positively influence effectiveness of project team learning.

3.3.5 The Use of Internet-Based Technologies

The definition of the use of Internet-based technologies in NPD project adopted in this thesis is based on the definition of IT use provided by Boynton *et al.* (1994) and states that the use of Internet-based technologies during development project is "the extent to which the project team deploys Internet-based technologies to support NPD project activities and processes". Based on the review of the relevant literature, the use of Internet-based technologies in this thesis is conceptualized as a four-dimensional construct, consisting of: Internet-based technology use to support data and information management; Internet-based technology use to support collaborative teamwork; Internet-based technology use to support external partners involvement; and Internet-based technology use to support project management and control. The items representing each dimension were developed based on the extensive literature review of empirical studies on the use of different information technologies in product development as well as on the nature of product development process (Boynton *et al.*, 1994; Busch *et al.*, 1991; Corso and Paolucci, 2001; Lewis *et al.*, 2004; Ozer, 2004; Kessler, 2003, Sethi *et al.*, 2003).

The development of the measurement tool for the construct of Internet-based technology use in NPD followed the procedure for developing measures with desirable reliability and validity properties proposed by Churchill (1979) and further modified by Ang *et al.* (2000). The first steps, i.e. to specify the domain of the construct as well as its dimensions, and to generate items to represent and measure each dimension were conducted based on the extensive literature review presented in Chapter 2. The summary of the remaining steps (pre-test of measurement items, collection of data, assessment of reliability, assignment of items to each measure of the four dimensions, assessment of validity, and establishment of the instrument) is reported together with the results of the statistical analysis of the collected data in Chapter 6. In order to measure the Internet-based technology use during a development project, respondents were asked to indicate the extent to which Internet-based technologies have been applied by the project team members to support the following activities:

<u>Data and Information Management</u>

1. Access and request product data and other information
2. Collect, store, categorize, and retrieve data and other information
3. Exchange messages with one another
4. Send, forward, receive, and reply to messages from other team members
5. Exchange files or documents with one another

<u>Collaborative Team Work</u>

1. Conduct virtual meetings of distributed team members
2. Provide virtual work environment for sharing resources and information
3. Providing virtual work environment for performing activities jointly and simultaneously
4. Provide real-time or near real-time communication among team members

<u>External Partners Involvement</u>

1. Communicate and exchange ideas with external partners/suppliers/customers
2. Obtain inputs and feedback from partners/suppliers/customers
3. Provide data sharing with external partners/suppliers/customers
4. Enable participation of external partners/suppliers/customers in virtual work environment

Project Management and Control

1. Coordinate activities performed by team members
2. Support project go-kill decision making
3. Monitor project schedule and budget
4. Conduct performance monitoring and assessments
5. Perform risk management activities

This approach has already been used in previous studies on IT use (Boynton *et al.*, 1994; Leenders and Wierenga, 2002; Johannessen *et al.*, 1999) and proved to be reliable. The scale to measure Internet-based technology use in NPD project was anchored as follows: 1 = none or to a little extent, 5 = to a very great extent. It is widely stated in the literature that Internet-based technology use can have positive impact on project integration, team learning, and communication quality. These relationships have been extensively discussed in the literature review presented in Section 2.3. Therefore, the following hypotheses are proposed:

Hypothesis 5 The use of Internet-based technologies during a development project will positively influence project team integration.

Hypothesis 6 The use of Internet-based technologies during a development project will positively influence effectiveness of project team learning.

Hypothesis 7 The use of Internet-based technologies during a development project will positively influence project communication quality.

Hypothesis 8 The use of Internet-based technologies during a development project will positively influence NPD project performance.

3.3.6 Moderating Influences

A premise of this thesis is that the impact of Internet-based technology use on NPD performance is not uniform across all the projects but is contingent on several contextual factors. Since it is hypothesized that Internet-based technologies can help achieve higher levels of team communication quality, team integration, and effectiveness of team learning, it can also be expected that the relationship between Internet-based technology use and NPD performance will especially depend on the different factors that determine the need for team integration, learning and communication. Three groups of moderating factors are investigated in this thesis: factors related to the environment, to the product, and to the project team. The following sections present a discussion of the hypothesized impact of moderating variables on the relationships among constructs in the proposed model.

3.3.6.1 Environmental Uncertainty

Environmental uncertainty can be defined as the unpredictability originating from the lack of clarity in information, the time span for feedback and the nature of causal relationships in the environment (Lysonski, 1985). Specifically, uncertainty arises from the unpredictability of various groups (e.g. suppliers, competition, customers) that make up the external environment of a business unit (Duncan, 1972). Environmental uncertainty is conceptualized as consisting of technological uncertainty, defined as the rate of technological change (Jaworski and Kohli, 1993; 1996) and market uncertainty, defined as the rate of change in the composition of customers and their preferences

(Jaworski and Kohli, 1993; 1996). Following the approach proposed by Jaworski and Kohli (1993) and applied in later studies (e.g., Agkün *et al.*, 2006), technological and market uncertainty was measured (on a 5-point Likert scale) by the respondents' level of agreement with the following statements, respectively:

1. The technology in the industry had been changing rapidly during the execution of the project.
2. Customers' preferences/requirements changed quite a bit during the execution of the project.

Environmental uncertainty is widely recognized as an important factor affecting NPD process and performance (Moorman and Miner, 1997; Bstieler and Gross, 2003; Agkün *et al.*, 2006). Development teams working in uncertain and turbulent environments are exposed to rapid technology changes, quick depreciation of know-how, short product cycles, dynamic markets with high entry and exit requirements, and rapidly changing customer preferences over time (D'Aveni, 1994). These teams have difficulty detecting meaningful cause-and-effect relationships, forming stable mental models of the market, and mastering new technologies (Dickson, 1992). In turbulent environments knowledge possessed by the team becomes very quickly obsolete, and the existing belief structure, norms, and cultures might no longer provide valid explanation of the new reality (Moorman and Miner, 1997). It further forces team members to revise their understanding of technology and to adapt to the changing knowledge and market (Moorman and Miner, 1997). Environment uncertainty, whether due to rapidly changing customer tastes and preferences, or a similarly disruptive event such as a new regulation, or a new technical discovery, disrupt the match between NPD process and environment and therefore can lead to team anxiety or team crisis (Agkün *et al.*, 2006). In this situation team members are confused, not familiar with the new relevant facts, unable to foresee the consequences of their actions, they often accuse each other, and are highly stressed. The frequent changes in information typical in environments with high uncertainty can also cause delays in communication, negatively affect communication quality, disrupt coordination, lead to intra-group conflict, role ambiguity, and decision making deficiencies. The existing theoretical and case-study based literature (see Section 2.3) indicates that the Internet-based technology use during product development can help to overcome the challenges related to the high level of environmental uncertainty. Therefore it is hypothesized:

Hypothesis 9 The impact of Internet-based technology use on NPD performance will be greater for projects conducted in environments characterized by high uncertainty compared to projects conducted in environments characterized by low uncertainty.

3.3.6.2 *Product Innovativeness*

Innovation literature suggests new product development projects should be distinguished by the degree of product innovativeness (Damanpour, 1991; Eisenhardt and Tabrizi, 1995; McDonough, 1993). In this thesis, the product innovativeness is defined (after Booz-Allen and Hamilton (1982)) as the product's newness to the firm and newness to the market. There are numerous ways of capturing product innovativeness in an empirical research; for an extensive discussion see, for example, the literature review conducted by

Garcia and Calantone (2002). In order to capture product innovativeness for the purpose of this thesis, the approach developed by Booz-Allen and Hamilton (1982) was modified and respondents were asked to choose the product category that best describes the product developed by their teams. The categories included:

- New-to-world product
- Product line new to the firm
- Addition to the firm's existing product line
- Major revision to an existing product
- Incremental change to an existing product

It is well established in the literature that products with different levels of innovativeness pose different requirements on the development project process and should be managed differently (Balachandra and Friar, 1999). Less innovative products are more certain and hence require a more structured process, with well-defined budgets and schedules. Compared to less innovative products, highly innovative products usually involve greater uncertainties and risks in terms of market acceptance, profitability, and the firm's capabilities to produce the product effectively and efficiently (Deszca *et al.*, 1999; Ozer, 2003). Their development also involves a greater proportion of experimentation and iterative problem solving, and therefore calls for more flexibility and greater levels of team learning effectiveness (Kessler, 2003).

It is also argued that highly innovative products in order to be successful require effort to be directed especially into the collection and use of information about the environment

(Cooper, 1999; Li and Calantone, 1998; Ozer, 2004). In their empirical research, Song and Montoya-Weiss (1998) confirmed that collection of information and team learning are important determinants of NPD performance in case of development of innovative products, but are not so critical in case of less innovative products. Also, in order to deal with the uncertainties related to highly innovative products, companies often need to create project teams that have different members (internal or external to the company) with different expertise. This in turn leads to greater need for high quality of team communication, high effectiveness of team learning and greater integration effort in case of highly innovative products as opposed to less innovative products.

Given the differences between the challenges of development of highly innovative and less innovative products, it can be expected that Internet-based technology will have different impact on NPD performance depending on the level of product innovativeness. In this study the following hypothesis is therefore proposed:

Hypothesis 10 The impact of Internet-based technology use on NPD performance will be greater for highly innovative products compared to less innovative products.

3.3.6.3 Product Complexity

Another factor expected to affect the role of Internet-based technology use during product development is product complexity. There are diverse conceptualizations of product complexity in the innovation literature. It has been viewed as "the degree of technology/engineering intensity and sophistication inherent in physical goods" (Lin and

Germain, 2004), "the number of different technologies or intricate parts or subassemblies the given product involves" (Sethi *et al.*, 2003), or "the number of functions designed into the product" (Griffin, 1997). The most widely accepted conceptualization of product complexity views it as having two aspects: *differentiation*, i.e. the number of varied product components to specify and produce; and *interdependence* (connectivity), i.e. the degree of interrelatedness/interactions (parts coupling) between these components that needs to be managed (Baccarini, 1996; Novak and Eppinger, 2001).

This conceptualization of product complexity has been criticized by several authors (e.g., Griffin, 1997) who argued that it limits the number of industries from which the data can be collected to only those manufacturing products containing parts. As Griffin (1997) pointed out, once this approach is adopted, then services and formulated products such as shampoo are difficult to include in the study. In order to overcome this weakness Griffin (1997) further suggested operationalizing product complexity as the number of functions designed into the product. Despite this concern, the definition of product complexity as differentiation of product parts and their interdependence is adopted, because it is more appropriate for the context of this thesis and is considered to provide more objective measures (Baccarini, 1996). According to the recommendations given by Baccarini (1996) and Novak and Eppinger (2001) product complexity was therefore measured by the extent to which respondent agreed with the following two statements:

1. The number of product parts in this product is very high.
2. Product parts in this product are highly interdependent.

Product complexity impacts NPD process by giving rise to integration challenges and by increasing the need for effective team learning. It is related to the fact that the design and development of complex products tends to be more costly and risky and is characterized by increased interdependence among internal and external participants in the NPD process. As a result, high levels of interaction among a variety of experts who very often are not physically proximate are often required (Malhotra *et al.*, 2001). Increased need for coordination in case of complex products is related to both the sources of product complexity: large number of parts and the high degree of their interdependence. Adding more modules to the product increases its complexity, due to the fact that each new part requires its own part drawing, testing and validation, and additional design work. Thus, adding more parts adds to the need for coordination necessary to ensure proficient product development (Novak and Eppinger, 2001).

At the same time, higher degree of interdependence among the product parts leads to a situation when making changes to a component is very likely to require changes in additional parts. This further requires that all part changes are coordinated with the designs of all the coupled parts. Thus, the more interconnected the product parts are, the more difficult it is to coordinate the activities involved in product development. Novak and Eppinger (2001) also pointed out that when a product is more complex, there is a greater need for additional effort directed at identifying and understanding all the interactions between product components, what further adds to the difficulty of coordinating development process and calls for effective team learning.

In general it can be concluded from NPD literature that high levels of integration, effectiveness of team learning and communication quality are especially needed in case of complex products. As a result, Internet-based technologies can play especially important role when complex products are being developed (Sethi *et al.*, 2003). Internet-based technologies can support the experts involved in development of complex product in their joint work on product design, in timely communication of changes in design, in ensuring that the designs of different parts are compatible with each other, and in obtaining feedback. Using Internet-based technologies can reduce the number of mismatches in designs and plans of different experts, reducing further the need for rework (Sethi *et al.*, 2003). Therefore, it can be expected that high level of Internet-based technology use during NPD project is likely to be more beneficial if the new product is very complex as opposed to situation when the new product is not complex. Thus, the following hypothesis is proposed:

Hypothesis 11 The impact of Internet-based technology use on NPD performance will be greater for highly complex products compared to less complex products.

3.3.6.4 Technology Novelty

Another factor that may significantly affect the relationship between Internet-based technology use during product development and NPD performance is technology novelty. The technology management literature describes technology novelty as "the degree of familiarity with the given technology" (Balachandra and Friar, 1999) or "the newness, to the development organization, of the technologies employed in the product development effort" (Tatikonda and Rosenthal, 2000). For the purpose of this study technology novelty is defined as "the extent to which the project team members are familiar with the technology they are using in the product being developed" (McDonough and Barczak, 1992). In order to measure technology novelty, the approach proposed by McDonough and Barczak (1992) was adopted and the respondents were asked to indicate the extent to which they agree with the following statement:

1. The technologies used in this product were new (unfamiliar) to the project team members.

The level of familiarity with the new product technology affects several aspects of development project. First of all, given the fact that product development entails risk, the degree of project team's familiarity with the product and process technology is likely to affect the degree of risk inherent in the given project in terms of the number and severity of problems that may arise (McDonough and Barczak, 1992). For example, when project team is familiar with the technology, the project has low technical risk because there is considerable existing knowledge regarding what is possible from a technological standpoint, how long it will take to complete the work, and how much and what kind of resources will be needed to accomplish the task. As a result the project becomes more of an engineering design undertaking.

On the other hand, an unfamiliar technology is a significant source of uncertainty (Daft and Lengel, 1986). The resulting lack of knowledge about process needed to accomplish the tasks successfully calls for more intense information processing and team learning. Project team members need to learn about technology and acquaint themselves with it. Conversely, project teams having a high degree of familiarity with the technology have less to learn and have a better knowledge about the direction to pursue. If an unfamiliar technology is needed for the development of the new product, the company may have to either develop it in-house or acquire it from another firm that has this technology. Therefore, it requires effective team learning processes, especially knowledge generation and transfer, as well as more flexibility. Given these needs of projects characterized by high technology novelty, it can be expected that Internet-based technology use will have more significant role during the development of products which involve technology unfamiliar to the project team as opposed to the development of products involving technology familiar to the project team. Therefore, the following hypothesis is formulated:

Hypothesis 12 The impact of Internet-based technology use on NPD performance will be greater for projects characterized by high technology novelty compared to projects characterized by low technology novelty.

3.3.6.5 *Functional Diversity in Team*

A criterion that makes an important distinction among development teams and is highly relevant for this thesis refers to the team's functional diversity, defined as "the degree of functional heterogeneity in the team" (Sarin and McDermott, 2003). This criterion refers to the number and characteristics of departments and external stakeholders represented on the development team (Ancona and Caldwell, 1992b). In order to assess functional diversity in team for the purpose of this thesis, the approach proposed by Sarin and McDermott (2003) was modified and applied. In their study Sarin and McDermott (2003) asked respondents to indicate how many members of their product development teams belonged to each of the following three functional areas: marketing, manufacturing and engineering. However, as numerous authors pointed out, NPD teams very often include also members from other functional areas or members from other organizations such as suppliers, retailers, business partners, or customers (e.g. Pitta *et al.*, 1996). Therefore, for the purpose of this thesis, each respondent was asked to indicate which of the following functional areas within his/her organization and external organizations were represented on the project team: marketing and sales, purchasing, manufacturing, research and development, engineering/design, customer support, suppliers, customers, and partner firms.

It is widely recognized that effective new product development requires that requisite diversity of viewpoints, disciplines, and functional specialties is represented on the project team (Imai *et al.*, 1985; Larson and Gobeli, 1988; Tushman, 1978; Denison *et al.*, 1996). However, at the same time, as the number of organizational departments and technical specialists represented on the project team increases, the project involves greater difficulties in management, coordination, and evaluation of design trade-offs (Clark and Fujimoto, 1991; Griffin, 1993; Meyer and Utterback, 1995). High levels of functional diversity, and especially the inclusion of external stakeholders, increases conflict, reduces cohesion, complicates internal communications, hampers coordination within the team, and presents significant management challenge (Kiesler, 1978; Shaw, 1971; Pitta *et al.*, 1996).

Activities involved in product development are very often performed with participation of external partners, such as suppliers, business partners, or customers. For example, suppliers with strong expertise in the relevant area may be involved in design and manufacturing of product's subassemblies, or they may suggest modifications to the product, etc. In such situations, a high level of interaction and coordination is needed between the main company developing the product and its suppliers in order to ensure that the parts made by suppliers are compatible with the main product. Similarly, if the company is developing a new product together with other partner companies, there is a need for high levels of communication, interaction and coordination between the company's design team and the designers from the partner companies. At the same time, the more inter-organizational linkages are involved in product development, the more there are sources of knowledge and opportunities for information acquisition (Powell, 1998; Hamel, 1991). In such cases, Internet-based technologies can be used to provide faster communication and improved coordination on NPD tasks, thereby improving NPD performance. Te following hypothesis is thus proposed:

Hypothesis 13 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by teams with high functional diversity compared to projects conducted by teams with low functional diversity.

3.3.6.6 Team Proximity

Another important aspect of NPD team is its proximity, defined as geographical dispersion of team members (Carbonell and Rodriguez, 2005). It has two aspects, i.e. whether the team members are collocated or not and whether they come from the same country. McDonough *et al.* (2001) distinguished among collocated, virtual and global NPD teams and argued that they significantly differ in terms of challenges faced. According to definitions provided by McDonough *et al.* (2001), collocated NPD teams consist of individuals who work together in the same physical location and are culturally similar; virtual NPD teams are comprised of individuals who have a moderate level of physical proximity and are culturally similar; and global NPD teams are compromised of individuals who work and live in different countries and are culturally diverse. For the purpose of this thesis, to capture team proximity, respondents were asked to indicate whether team members were located:

- In one building/office
- In several locations, but one city
- In several cities, but one country
- In more than one country

More and more often companies are relying on NPD teams that are dispersed throughout the world mostly due to global dispersion of company's resources and facilities and the difficulty and expense associated with relocating these resources and facilities to a central location; as well as in order to be able to handle the increased complexity in product development and gain access to the needed expertise (Boutellier *et al.*, 1998).

While distributed teams may have the potential to offer higher performance, they often fail to realize that potential (McDonough *et al.*, 2001). This lower than expected performance is often related to the fact that distributed teams face greater challenges than collocated teams. Among these challenges are the difficulty in achieving an effective level of integration and in fostering effective communication among team members (McDonough *et al.,* 2001). The geographical dispersion of team members makes communication among them quite complex. As a result, dispersed teams significantly increase the team's communication and integration requirements (Robey *et al.*, 2000; Graber, 1996; Subramaniam *et al.*, 1998).

The studies on distributed teams have found that Internet-based technologies were useful in facilitating or even enabling communication across groups and employees located at dispersed geographical locations. Robey *et al.* (2000) argued that Internet-based technologies make it possible to adopt virtual organizational forms that operate more independently of time and space than traditional organizations. Pitta *et al.* (1996) further argued that information technology represents one of the necessary conditions for effective boundary-spanning team. As a result, literature review indicates that Internet-based technology use as well as its impact on NPD performance will differ depending on the dispersion of NPD team. It is therefore expected that Internet-based technologies will play significantly more important role in projects were teams consist of members dispersed geographically as opposed to projects were teams consist of collocated members. The following hypothesis is therefore proposed:

Hypothesis 14 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by highly dispersed teams compared to projects conducted by collocated teams.

3.3.6.7 Team Size

Team size represents the next variable hypothesized to moderate the relationship between Internet-based technology use and product development performance. In order to capture team size, the respondents were asked to indicate the total number of project team members from within their company and external to their company. Team size is considered in the literature to be a very important factor affecting the team's requirement of communication, integration and learning effort. The more members the team has, the more challenging effective communication becomes, and there needs to be more effort devoted to ensuring that all team members receive the relevant for them information.

Similarly, team size affects team learning, both positively, by creating opportunities for more intensive learning and providing access to knowledge possessed by all the team members, and negatively, by creating barriers to effective learning by increasing the number of interactions and communication flows required to make decisions and achieve consensus. Larger teams also require greater effort aimed at developing sufficient team integration, in particular at coordinating all the activities and building social integration. As it was demonstrated in the literature review, Internet-based technologies are believed to provide opportunities and tools for improvement of communication quality, integration and effectiveness of learning in the team, and therefore it can be expected that they will play more important role in projects executed by large teams, than in projects executed by small teams. It is thus hypothesized:

Hypothesis 15 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by large teams compared to projects conducted by small teams.

3.3.6.8 Team Stability

The last variable hypothesized to moderate the relationship between the use of Internet-based technologies and NPD performance is team stability. A stable team is defined as a team with low membership turnover; while unstable team is defined as a team with high membership turnover (Akgün *et al.*, 2005). In order to measure team stability, the measurement tool proposed by Akgün and Lynn (2002) was applied. The respondents were asked to indicate the degree to which they agree with the following statements:

1. Most of the project managers and leaders who started this project remained on it from start to completion.
2. Most of the team members who were on the team remained on it from start to completion.
3. Most of the team members were assigned to this project on a full-time basis.
4. Most of the team members worked together on previous development projects.

Research on team stability has emphasized that high turnover causes disruption in team functioning and decrease in team performance due to knowledge depreciation. For example, Akgün and Lynn (2002) in their study of 211 NPD projects found that team stability had a positive impact on team learning and project success. They explained their findings by pointing out that when a member left the team, the team has lost a valuable knowledge and information resource. Further, new team members may disrupt the established beliefs, practices, effectiveness of team learning and team integration, because the new information and knowledge brought in by new members may affect shared understanding and established procedures (Akgün *et al.*, 2005). Members joining the team at different times do not have many opportunities for interaction, undergo disparate experiences, develop different perspectives, and are not as attracted to one another as members who arrived at the same time (Ancona and Caldwell, 1992b). New product development is therefore more challenging when the team is highly unstable. In order to overcome these challenges, the Internet-based technologies can be applied to facilitate preserving and sharing the knowledge of the former team members as well as to integrate the new members into the team. It is therefore expected that the use of Internet-based technologies can support a team in overcoming the negative effects of team instability. It is hypothesized that:

Hypothesis 16 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by unstable teams compared to projects conducted by stable teams.

3.4 Conclusions

Chapter 3 provided summary of the model and description of all the variables and hypotheses. A summary of the constructs and their measurement is provided in Appendix A. A list of the hypotheses is provided in Appendix B.

CHAPTER 4

RESEARCH METHODOLOGY

This chapter presents the research methodology employed in this study. It includes a discussion of the research design, data collection (sampling frame and sampling design), and survey instrument development. This chapter also discusses the questionnaire response rate.

4.1 Research Design

The current stage of knowledge regarding the relationship between Internet-based technology use during NPD project's execution and NPD performance is limited. The existing theoretical models have been developed in relative isolation from one another and, in most cases, were not tested empirically. Additionally, prior empirical research in this field has relied almost exclusively on the use of case studies to explain the relationships of interest. Data gathered through case study methods are informative and help to understand the nature of relationships in a given context, but do not provide basis for empirical generalization.

In order to explore the role of Internet-based technologies in NPD projects, this study applies quantitative research methods. Quantitative research is concerned with discovering general rules and processes within the population of interest (Davis, 1996).

Quantitative research methods rely on statistical methods to describe specific aspects of phenomena. Very important part of the quantitative research is the development of the research instrument, which may include test items, survey questions or other types of measurement tools (Patton, 1990). The research instrument has to be developed in advance, tested, revised, and then carefully administered in a standardized manner. As a result, the research process is highly structured and researchers usually have very little or no interaction with those under study.

In order to collect data for testing of the research model proposed in this thesis, a survey methodology was applied. Survey approach involves collection of data from a sample of individuals through their responses to questions (Schutt, 1999). There are a number of reasons for employing survey research design rather than an experiment or a field study. Surveys allow researchers to study and describe large populations fairly quickly at a relatively low cost (Davis, 1999); they have high versatility (can be adapted to almost any research settings) and generalizability (Davis, 1999); and they are the recommended method for collecting original data from populations too large to observe directly (Kerlinger and Lee, 2000). Given the purpose of this study, survey has been chosen as a preferred approach, because numerous case studies describing the use of Internet-based technologies in product development already exist. What is missing is a large scale study that would test the conclusions drawn from these case studies and would explain contradictory findings from different case studies.

4.2 Sampling Frame

Since the focus of this study is the impact of Internet-based technology use on NPD performance conceptualized as product quality, time-to-market, and development cost, the attention is centred on processes at the project level. The unit of analysis is therefore the individual NPD project. The sampling frame for this study comprises of managers of product development projects from Canadian and American manufacturing companies. To enhance the generalizability of the findings, a sampling frame that is a cross-section of several high-tech industries where the use of Internet-based technologies is more likely was chosen. The high-tech industries were chosen as a context because of their high level of product development activity using cross-functional NPD teams (Ancona and Caldwell, 1990, 1992a,b; Sarin and Mahajan, 2001; Sarin and McDermott, 2003). Also, the high environment uncertainty surrounding these industries along with short product lifecycles create a need to develop knowledge-based, learning-intensive teams. Thus, given the team learning emphasis of this study, the high-tech industries were considered to provide a suitable context.

The industries selected for this study are represented by North American Industry Classification System (NAICS) codes and include the following industries: machinery manufacturing (NAICS Code of 333), computer and electronic products manufacturing (NAICS Code of 334), electrical equipment, appliance, and component manufacturing (NAICS Code of 335) and transportation equipment manufacturing (NAICS Code of 336). Lists of organizations possessing these NAICS codes have been obtained from two commercial directories: the *Scott's Online Directory* for Canadian manufacturing organizations and the *Manufacturers News, Inc. Directory* for American manufacturing organizations. Only organizations having more than 25 employees were included in the sampling frame. The actual selection of the units to be contacted followed the probability sampling design. 1000 organizations were randomly selected (following simple random sampling process) from the list of companies obtained from the Scott's Online Directory. Similarly, 1500 organizations were randomly selected (following simple random sampling process) from the list of companies obtained from the Manufacturers News, Inc.

4.3 Survey Instrument Development

As it was explained earlier, this thesis applied survey approach. A survey kit, including a cover letter, a questionnaire, and a self-addressed stamped return envelope, was developed and mailed to NPD project managers from the companies from the sampling frame.

The questionnaire included the measurement items for all the constructs, several demographic questions and open ended question regarding NPD practices. Wherever possible, measurement items were adapted from existing scales from the literature. Using scales that have been tested in previous studies is recommended, because it helps to assure instrument reliability. For new measures and for measures that required significant modification, the standard psychometric scale development procedures were followed (Churchill, 1979; Bagozzi and Philips, 1982; Gerbing and Anderson, 1988; Moore and

Benbasat, 1991; Boudreau *et al.*, 2001). First, the domain of the relevant construct was specified. Second, a pool of measurement items was developed based on the conceptual definition of the construct and the items ability to convey different, yet related aspects of the construct, as recommended by Nidumolu and Knotts (1998). For the constructs that have not been extensively studied empirically before, such as Internet-based technology use, a literature review was conducted as a starting point to establish the theoretical foundation and thus content validity. Also, where it was possible items were identified from existing scales and then employed in this study.

The next stage of the survey instrument development process involved developing initial version of the questionnaire and pretesting it in a group of project managers and scholars knowledgeable in the area of product development. This allowed modification of questions that were not clear and identification of potential problems with the design of the questionnaire regarding wording or format. Based on the results of this stage, the questionnaire was modified in a way that addressed the concerns raised. The items finally chosen to measure the constructs included in the research model are reported in Appendix A.

4.4 Questionnaire Response Rate

Once the process of survey development was completed, the survey kit was mailed to the randomly selected NPD managers from Canadian and American companies operating in the selected four manufacturing industries. A total of 2500 survey kits were mailed. In order to further encourage participation, a follow-up phone calls to the appropriate persons were made. Also, the researcher traveled to companies in the local regions, including Hamilton and Toronto, to deliver research kits in person and to invite research participation.

Out of the 2500 product development managers who were mailed the survey, 309 responded, either by returning the filled out questionnaire or responding to the researcher (mostly by phone or e-mail) explaining why they were not able to participate in the study. At the same time, 46 questionnaires were returned undelivered. The overall response rate is therefore 12.6% calculated as 309/(2500-46). However, of these 309 responses, 31 were unusable. As a result, the usable number of questionnaires for this study is 278 which gives a usable response rate of 11.3%.

There were several reasons for rejecting the 31 responses considered unusable. Eight were returned empty with no explanation given as to why they were not completed. In eleven questionnaires respondents indicated that they either do not conduct product development activities at all, or do not conduct them at their location. In two cases, although the companies conducted product development activities, they were done for other companies and therefore the company contacted was not concerned with the product development process and its performance, but only with the engineering done following the specifications received from the customer. Three more respondents explained that their development activities are small-scale and in each case conducted by one person only, so they did not feel that they could contribute to the study. Three other respondents indicated lack of interest in Internet-based technologies and lack of their use in their organizations as a reason why they did not filled out the questionnaire. The remaining four questionnaires were rejected because the respondents left the majority of questions unanswered.

CHAPTER 5

DESCRIPTIVE STATISTICS

5.1 Profile of Responding Companies

The organizations that responded to the survey represent all of the four industries that were selected to be in the sampling frame. Majority (167) of the organizations are from Canada and the remaining 111 are located in the United States. When asked about the location of the head office, 142 companies (representing 51.1% of the respondents) indicated that their head office is located in Canada, 115 companies (representing 41.4%) of the respondents) indicated that it is located in the United States, while the remaining 21 companies have their head offices located in Germany (5 companies), the United Kingdom (4 companies), France (3 companies), Belgium (2 companies), Japan (2 companies), Denmark, Sweden, Ireland, Italy and Switzerland (1 company each).

The size of the companies that participated in this study ranges from 5 employees to over 2000 employees, see Figure 5.1. Majority of the companies, representing 87.8% of the sample, had less than 1000 employees (1 company had 5 employees, 40 companies had between 25 and 49 employees; 66 companies had between 50 and 99 employees; 111 companies had between 100 and 499 employees; and 26 companies had between 500 and 999 employees). The remaining 34 respondents, representing 12.2% of the sample, indicated that the number of employees in their organization is either between 1000 and

2000 (15 companies) or above 2000 (19 companies). However, most of these respondents also indicated that their local offices operate quite independently from the head office and do not exceed 500 or at most 1000 employees. Therefore, the actual range of size is not that extreme and the companies even with more than 2000 employees worldwide were still included in the analysis, as their local offices were expected not to exceed 1000 employees.

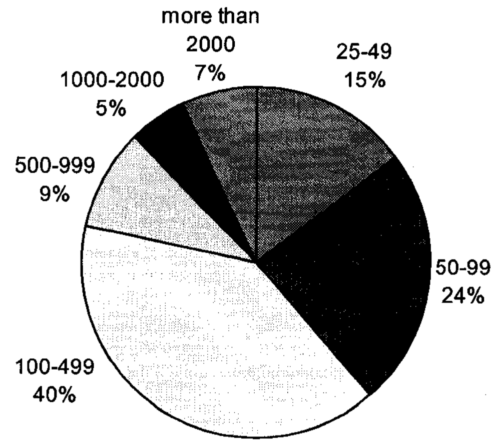


Figure 5.1 Distribution of respondent companies by the number of employees

5.2 Product Development Projects

The respondents were asked to answer the questions in the survey based on a specific new product development project that was either completed recently in their organization or is near completion. Majority of the respondents chose projects that were completed within the last 2 years (174 projects, representing 62.6% of the sample). The projects that were near completion, amounting to 92 projects, represented 33.1% of the sample. The remaining 11 projects (4.0% of the sample) were completed between 2 and 5 years ago and 1 project was completed more than 5 years ago.

The projects included in the sample differed by their level of innovativeness. The largest group (30.9% of the sample) consisted of major revisions to existing products and included 86 cases. Additions to the firm's existing product lines represented 23.7% of the sample (66 cases) while product lines new to the firm represented 24.1% of the sample (67 cases). The remaining projects were either new-to-world products (41 cases, representing 14.7% of the sample) or incremental changes to existing products (18 cases, representing 6.5% of the sample).

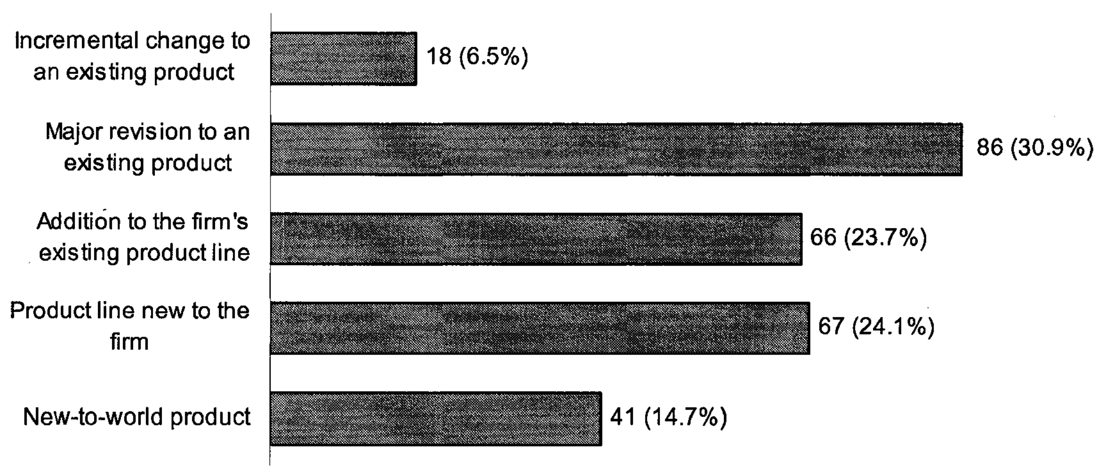


Figure 5.2 Distribution of projects by the level of their innovativeness

The projects differed also by their duration. For 6 cases the information about the duration of the new product development project was missing. For the remaining 272 cases, the average project duration was 1.674 years with standard deviation equal 1.062. The project duration ranged from 0.1 year to 5 years, with majority of the development projects taking 1 year or less (114 cases). The remaining projects either took more than 1 year but less or equal to 2 years (102 cases) or more than 2 years (56 cases).

5.3 Project Teams

The development projects included in the sample were executed by project teams. As it was indicated earlier, three respondents indicated that the projects in their organizations are executed by one person only and therefore either did not fill out the survey or were not included in the analysis due to the amount of missing values in their responses.

The product development teams differed significantly in their size and complexity. There were different functional groups represented on development teams, including marketing and sales, research and development (R&D), purchasing, engineering/design, manufacturing, quality assurance, and customer support. The functional group most frequently represented on the projects was engineering/design, present on 255 projects (91.7% of the sample), followed by manufacturing (present on 223 projects or 80.2% of the sample), R&D (present on 222 projects or 79.9% of the sample) and marketing (present on 221 projects or 79.5% of the sample). The purchasing department was represented on 178 projects (64.0% of the sample) while the customer support was represented on only 74 projects (26.6%), see Table 5.1.

Table 5.1 Functional composition of development teams

Engin/Design	Manufacturing	Marketing	R&D	Purchasing	Customer Support	# of projects
■	■	■	■	■	■	37
■	■	■	■	■		59
■	■	■	■		■	9
■	■	■		■	■	7
■	■		■	■	■	5
■		■	■	■	■	2
Number of development teams with representatives from at least 5 functional areas:						**119**
■	■	■	■			24
■	■	■		■		17
■	■		■	■		12
■		■	■	■		18
	■	■	■	■		2
■	■	■			■	2
■	■		■		■	2
■		■	■		■	4
	■	■	■		■	1
■	■			■	■	2
Number of development teams with representatives from 4 functional areas:						**84**
		■	■		■	1
■		■			■	1
		■	■	■		2
	■		■	■		4
■		■		■		1
■	■			■		8
	■	■	■			5
■		■	■			12
■	■		■			15
■	■	■				7
Number of development teams with representatives from 3 functional areas:						**56**
■					■	1
	■			■		1
■				■		1
		■	■			6
■			■			2
■		■				4
■	■					3
Number of development teams with representatives from 2 functional areas:						**18**
	■					1
Number of development teams with representatives from only 1 functional area:						**1**
23	55	57	56	100	204	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Total:278

■ The functional area is represented on the development team

□ The functional area is not represented on the development team

Exactly 119 of the project teams included members from at least 5 functional areas (37 teams had representatives from all the six functional areas). Teams with members from four functional areas represented over 30.5% of the sample and amounted to 84 cases. Also there were 56 teams with members from 3 functional areas and 18 teams with members from only 2 functional areas. Only one team had members from just one functional area, manufacturing. The majority of the development teams in the sample were therefore highly cross-functional in nature. It is also important to note that there were no projects that would not have at least one of the following departments represented on the team: engineering, manufacturing or R&D. The projects that did not have team members from either engineering or manufacturing, always had members from both R&D department and marketing department. Six respondents also indicated that their development teams had at least one representative from quality assurance function.

Majority of the projects also involved representatives of external organizations (suppliers, customers, partner firms) on their teams. Suppliers' representatives were involved on 173 teams (62.2% of the sample). Customers' representatives were present on 153 teams (55% of the sample). Finally, partner companies were involved on 46 projects (16.5% of the sample). Some respondents also indicated that their project team had representatives from universities (2 respondents), industrial design or general consulting companies (4 respondents), and patent lawyers (1 respondent).

The development projects included in the sample were executed by teams consisting of the average of 14.35 members, with standard deviation equal to 18.25 (N = 277).

However, if three most extreme cases (teams of 110, 130 and 215 members) are not included in the calculations of the average team size, the average team size is 12.85 with standard deviation of 10.28 (N = 274). The number of project team members in the sample ranges from 2 to 215 members[1]. Majority of the project teams have between 2 and 10 members (145 teams). The second largest group of projects has between 11 and 20 members (91 teams). The remaining project teams have either between 21 and 50 members (34 teams) or between 51 and 215 (7 teams).

The number of team members from the respondent company (internal members) on the project teams ranged from 1 to 215 (N = 277, as one respondent did not indicate the number of internal team members). However, if one outlier of 215 internal members is not taken into consideration, the range of internal team size would be 1 to 50. The average internal team size is 9.722 with standard deviation of 14.25 (N = 277, extreme value of 215 included) or 8.978 with standard deviation of 7.075 (N = 276, extreme value of 215 excluded). Majority of the projects (261) had no more than 20 internal members. The remaining 16 projects had between 21 and 215 internal team members. The number of external team members on the project teams ranged from 0 to 100, with average equal to 4.645 and standard deviation equal to 10.163 (N = 276 given 2 missing values). Out of 278 projects, 86 had no external members on their teams. 181 projects had at least one

[1] There was one respondent who indicated that there was only one internal team member on the team and no external team members. However, at the same time the respondent indicated that representatives of multiple functional areas, as well as suppliers and customers were present on the team. As a result, an assumption was made that his team consisted of more members and his response was included in the analysis (in the category of between 2 and 10 members). One respondent did not indicate team size.

external member, but no more than 20 external members. The remaining 9 projects had between 23 and 100 external team members.

In case of 73 projects (26.3% of the sample) all the team members were located in one building or office. The team members in 46 projects (16.5% of the sample) were located in several locations across one city. The remaining projects had team members located in several cities within one country (74 projects representing 26.6% of the sample) or in more than one country (85 projects representing 30.6% of the sample).

5.4 Internet-based Technology Use

The respondents were asked about their Internet-based technology use in two ways. First of all, in order to measure the construct of IBT use as conceptualized in this thesis, they were asked to indicate the extent to which Internet-based technologies were applied by the team to support a series of NPD activities across four dimensions: data and information management, collaborative team work, external partner/supplier/customer involvement, and project management and control. The answers to these questions are analyzed further, when the model proposed in this thesis is tested.

However, the respondents were also asked to indicate to what extent they were using different Internet-based technologies provided in the questionnaire in a form of a list of technology types. The types of technology that were listed and the answers about the extent of their use are presented in Figure 5.3.

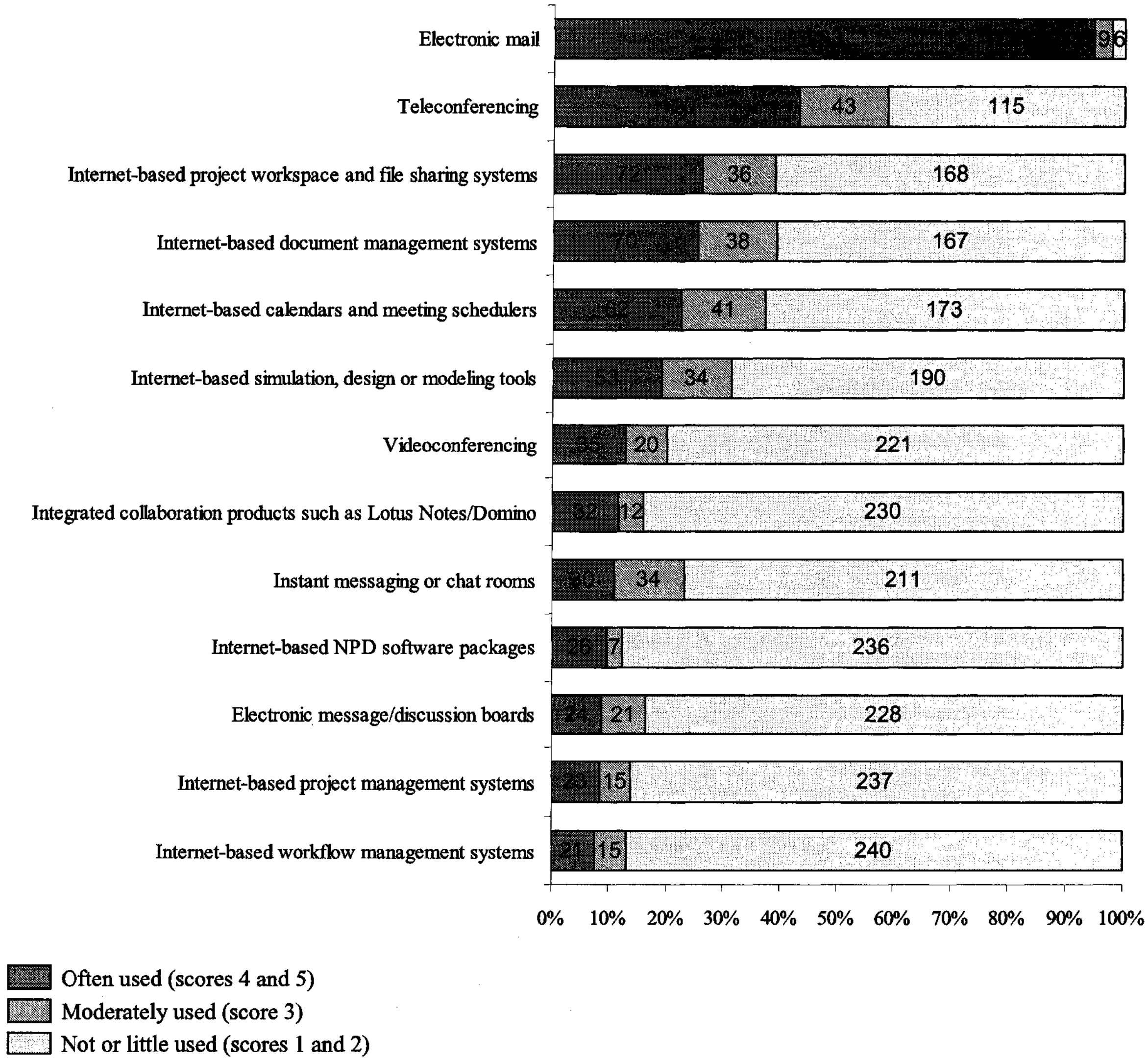


Figure 5.3 Internet-based technology use by technology type

The two technologies most often used were email and teleconferencing, used extensively or moderately by over half of the respondents. The remaining technologies were not adopted so frequently.

CHAPTER 6

DATA PREPARATION

This chapter presents the data preparation and analysis that were performed before the actual testing of the hypotheses was conducted. First, the approach of structural equation modeling chosen to test the proposed model and hypotheses is introduced. A summary of the results of data screening is then presented. This is followed by a discussion of the analysis conducted in order to verify the validity and reliability of the measures used in the study.

6.1 Introduction to Structural Equation Modelling

In order to perform the analysis of the data collected for the purpose of this thesis, the structural equation modeling (SEM) technique was applied. There are several reasons for choosing this technique. The main reason why SEM was chosen is the fact that, unlike multivariate ANOVA and canonical correlation, which can only deal with a single relationship between dependent and independent variables, SEM is an approach that addresses the issue of multiple relationships occurring simultaneously (Kerlinger and Lee, 2000). Within the limits of identification, SEM also allows great flexibility in how the equations describing relationships among variables are specified. It is also a recommended approach to conduct reliability and validity analysis of the measurement model (Anderson and Gerbing, 1988).

Structural equation modeling, also called *latent variable structural equation modeling*, or *analysis of covariance structures,* is a method designed for representing, estimating, and testing theoretical frameworks of relationships among variables, where those variables may be either observable or unobservable (Rigdon, 1998). The structural equation model, in its most general form, consists of a set of linear structural equations. The equations contain random variables, structural parameters, and sometimes, nonrandom variables. The three types of random variables are: directly *observed variables* (also called *manifest variables*); unmeasured *latent (theoretical) variables* that are not observed but are related to the observed variables; and d*isturbance/error variables* (Bollen, 1989). The nonrandom (fix, nonstochastic) variables are explanatory variables whose values remain unchanged in repeated random sampling. There are less common than random explanatory variables. Both observed variables and latent variables can be considered as independent variables or dependent variables, given the context of the study.

In SEM it is assumed that the observed variables are indicators of the latent variables and that there is a causal structure among the set of latent variables. The model therefore consists of two parts, *the measurement model* and *the structural equation model.* The measurement model describes how the observed variables indicate and explain the latent variables i.e., describes the factor (latent variables) structure. At the same time it describes the measurement properties (reliability and validity) of the observed variables. On the other hand, the structural equation model specifies the connections (causal relationships) between the latent constructs. Structural equation models can take several different forms. For example, a single independent latent variable can predict a single dependent latent variable, several latent variables can correlate in the prediction of a single dependent variable, or one independent latent variable can predict another latent variable, which in turn predicts the third latent variable. The structural equation modeling allows for multiple latent constructs indicated by observable variables (both independent and dependent) and for recursive and nonrecursive relationships between constructs.

Structural equation models encompass a wide range of models, for example univariate and multivariate regression models, path analysis models, or factor analysis models (Marcoulides and Schumacker, 1996). The general SEM model can be represented by three matrix equations, see Bollen (1989). Let us introduce the following terms:

η denotes a m x 1 vector of endogenous latent variables
y denotes a p x 1 vector of manifest items for the endogenous latent variables η
ε denotes a p x 1 vector of disturbances in measurement model for η
Λ_y is a p x m matrix of manifest items loadings in measurement model for η
ξ denotes a n x 1 vector of exogenous latent variables
x denotes a q x 1 vector of manifest items for the exogenous latent variables ξ
δ denotes a q x 1 vector of disturbances in measurement model for ξ
Λ_x is a q x n matrix of manifest items loadings in measurement model for ξ
Γ is a m x n matrix of loadings of the exogenous latent variables ξ in the structural model
B is a m x m matrix of loadings of the endogenous latent variables η in the structural model
ζ is a m x 1 vector of disturbances in the structural model

The equations for the full model are given as follows. The structural equation model is given as:

$$\eta = \mathbf{B}\eta + \Gamma \xi + \zeta \qquad (1)$$

The measurement model for η is given as:

$$\mathbf{y} = \Lambda_y \eta + \varepsilon \tag{2}$$

and the measurement model for ξ is given as:

$$\mathbf{x} = \Lambda_x \xi + \delta \tag{3}$$

SEM procedure tests the model by assessing whether a sample covariance or correlation matrix is consistent with a matrix implied by the model specified by the researcher (Rigdon, 1998). Therefore, the necessary inputs for SEM are either row data or sample moments computed from the data (variances and covariances, correlations or other moments) and the model that is going to be evaluated. In case of this thesis, the input was in the form of raw data. The model consists of a set of suggested equations, with some parameters fixed to particular values and others left for estimation.

There are many different methods of estimation of path coefficients in structural equation modeling. The general purpose of all these methods is to estimate the parameters of the model from the sample covariance matrix S. For a precise definition of different methods, see, for example, Jöreskog and Sörbom (1989) or Kline (2005). For the purpose of this study the full information maximum likelihood method (FIML) was applied. Maximum likelihood estimators are known to be consistent and asymptotically efficient in large samples. It is important to note that this method requires data to be continuous. Although in this study the responses are measured on a 5-point Likert scale, they are considered to be good approximation of continuous variables. Simulation studies (Bollen, 1989) confirm that for reasonably large samples, when the number of Likert categories is 4 or higher and skew and kurtosis are within normal limits, use of maximum likelihood estimation is justified.

Application of SEM procedure leads to several general groups of results. They include: estimates of the model parameters and estimates of their standard errors; measures of model fit which assess the overall consistency between the specified model and the data; and diagnostic statistics, which help to identify the sources of any fit problems (Hoyle, 1995). The application of structural equation modeling for the purpose of this thesis included three main stages: data screening, confirmatory factor analysis (CFA) to test the reliability and validity of the measurement model, and testing of the structural model, i.e. testing the hypothesized relationships among the constructs. The analysis was conducted using LISREL 8.80 software package.

6.2 Data Screening

Before the actual testing of hypotheses can take place, research specialists strongly recommend performing data screening in order to improve confidence that the main analysis will produce valid conclusions. Mertler and Vannatta (2001) suggested that there are four reasons for performing the screening of the data: (1) to avoid inaccuracy of the data that have been collected; (2) to identify missing data and determine the best strategy for dealing with them; (3) to assess the effect of extreme values (outliers) on the analysis; and (4) to assess the adequacy of fit between the data and the assumptions upon which the statistical methods are based.

6.2.1 Data Entry Inaccuracy and Missing Data

The collected data were recorded manually into a Microsoft Excel file. The coded data were double checked with the actual survey responses to ensure accurate data entry.

Analysis of the missing data in the set of responses collected for the purpose of this thesis indicated that except for two questions, all variables contained less than 10.5% of missing information, with majority containing less than 4% of missing data. However, the following two questions contained more than 30% of missing values:

- "Please rate the time taken to develop and launch this product as compared to time taken to develop and launch similar products by your nearest competitors" (measure of time-to-market)
- "Please rate the total project cost as compared to the total cost of similar projects executed by your nearest competitors" (measure of development cost)

The large number of missing values in the responses to these two questions can be related to several factors. First of all, some respondents did not reply because they did not have this kind of information about their competitors. Second, in several cases the questions turned out not to be applicable, as the products under considerations were highly innovative and the competitors did not conduct similar projects. The two questions with the largest number of missing values were originally asked as part of a measurement tool to assess the performance of the projects conducted by the respondents. However, given the low response rate to these questions the decision was made to exclude them from the analysis and base the analysis on the remaining items measuring NPD performance.

In order to properly deal with the missing data in the responses to the questions that were included in the final analysis, it is necessary to determine the pattern of the missing data. There are many possible reasons why the data set may be incomplete. Rubin (1976) proposed a classification for missing data mechanisms and argued that missing data can be ignored (i.e., unbiased estimates can be obtained) under the condition that data are missing completely at random (MCAR) or missing at random (MAR). MCAR refers to data missing on a variable where presence or absence of the observation is independent of other observed variables and the variable itself. This is a stringent assumption that may not be justifiable in practice (Muthén *et al.*, 1987). Less restrictively, MAR allows the presence or absence of an observation to depend on other observable variables, but not on the variable from which the value is missing. For the purpose of this thesis it was assumed that the missing data were missing at random.

The issue of missing data needs to be carefully addressed, otherwise the use of inappropriate methods for handling missing data can lead to bias in parameter estimates (Jones, 1966), bias in standard errors and test statistics (Glasser, 1964), and inefficient use of data (Afifi and Elashoff, 1966). There are several methods available for handing missing data in the estimation of structural equation models. They include: listwise deletion (LD), pairwise deletion (PD), data imputation (Graham and Hofer, 2000; Rubin, 1987), and maximum likelihood methods, i.e., full information maximum likelihood estimation (FIML), also known as the individual raw-score likelihood method (Enders and Bandalos, 2001); multiple-group approach (Allison, 1987; Muthén *et al.*, 1987; McArdle, 1994); and the expectation-maximization (EM) algorithm (Dempster *et al.*, 1977; Allison, 2003).

In order to handle missing data in the analysis conducted for the purpose of this thesis, FIML approach was applied. This choice was related to the assumption of MAR made earlier - the most common missing-data methods (LD and PD) could not be applied, because they yield unbiased parameter estimates only when MCAR holds, but lead to biased parameter estimates under MAR. Another reason to avoid these methods is related to the fact that they also can drastically reduce the size of the data set available for model estimation, especially in case of listwise deletion (Bollen, 1989). Given that the sample size in this thesis is 278, it was crucial to avoid any reduction of the data set in order not to compromise power of tests. The choice of full information maximum likelihood method for the purpose of this thesis was also motivated by the results of earlier Monte Carlo simulations comparing performance of four most commonly used methods (i.e., listwise deletion, pairwise deletion, data imputation and full information maximum likelihood method). These simulations indicated the superiority of FIML, as the method leading to the lowest rate of convergence failures, least bias in parameter estimates, and lowest inflation in goodness of fit statistics (Enders and Bandalos, 2001; Brown, 1994).

6.2.2 Outliers

Data was screened for outliers using a technique suggested by Stevens (1996). Outliers in multivariate data consist of unusual combinations of scores on two or more variables. Outliers in multivariate data using Likert type scales are difficult to identify using traditional detection techniques for univariate situations. Therefore, in order to detect outliers, the Mahalanobis distance was calculated. The Mahalanobis distance is defined as the distance of a case from the centroid of the remaining cases where the centroid is the point created by the means of all variables. In case of the data collected for the purpose of this thesis, the Mahalanobis distance was calculated as a chi-square statistic with degrees of freedom equal to the number of variables in the analysis. No outliers were detected during the analysis.

6.2.3 Normality

In structural equation modeling it is assumed that random components in the model have distribution that belongs to the family of elliptical distributions, such as multivariate normal distribution. The random components in the structural equation modeling are also assumed to satisfy the following minimal assumptions: measurement errors in $\mathbf{x}$ are uncorrelated with exogenous latent variables, measurement errors in $\mathbf{y}$ are uncorrelated with the endogenous latent variables, errors in the structural equation model are uncorrelated with exogenous latent variables, with the measurement errors in $\mathbf{x}$, and with measurement errors in $\mathbf{y}$.

In order to assess the normality of the data, the values of skewness and kurtosis for all the variables were calculated. Skewness is a measure of the asymmetry of a distribution. The normal distribution is symmetric and has a skewness value of zero. An excessive skewness exists when test values are outside the range of -2 to +2 (Curran *et al.*, 1996). The statistics for the individual items (Table 6.1) indicate that the items tend to be skewed, i.e, their distributions are asymmetric and extend towards the high end of the scale. However, there are no cases of excessive skewness.

Table 6.1 Descriptive statistics of all indicators

Item*	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation	Skewness Statistic	Kurtosis Statistic
Items related to Internet-based technology use:								
IBT_A1	278	1	5	4.076	0.058	0.964	-0.956	0.339
IBT_A2	278	1	5	3.727	0.066	1.100	-0.539	-0.553
IBT_A3	278	1	5	4.245	0.062	1.026	-1.334	1.054
IBT_A4	278	1	5	4.180	0.063	1.053	-1.263	0.846
IBT_A5	278	1	5	4.126	0.063	1.049	-1.143	0.612
IBT_B1	276	1	5	2.580	0.083	1.382	0.287	-1.227
IBT_B2	277	1	5	2.798	0.081	1.344	0.058	-1.211
IBT_B3	276	1	5	2.659	0.081	1.340	0.203	-1.180
IBT_B4	277	1	5	3.054	0.082	1.360	-0.186	-1.184
IBT_C1	274	1	5	3.734	0.069	1.144	-0.616	-0.560
IBT_C2	273	1	5	3.678	0.071	1.178	-0.669	-0.431
IBT_C3	273	1	5	3.498	0.079	1.301	-0.470	-0.971
IBT_C4	271	1	5	2.550	0.087	1.431	0.430	-1.167
IBT_D1	277	1	5	3.332	0.075	1.247	-0.346	-0.872
IBT_D2	266	1	5	2.868	0.082	1.329	0.049	-1.186
IBT_D3	277	1	5	3.000	0.079	1.308	-0.098	-1.098
IBT_D4	273	1	5	2.828	0.079	1.299	0.060	-1.098
IBT_D5	268	1	5	2.534	0.078	1.285	0.304	-1.125
Items related to communication quality:								
CQ1	278	1	5	3.827	0.055	0.922	-0.817	0.675
CQ2	278	1	5	3.813	0.061	1.013	-1.003	0.903
CQ3	278	1	5	3.770	0.062	1.039	-0.906	0.521
CQ4	278	1	5	3.640	0.058	0.969	-0.713	0.386
CQ5	278	1	5	3.694	0.061	1.011	-0.773	0.400

Item*	N	Minimum	Maximum	Mean	Std. Error	Std. Deviation	Skewness Statistic	Kurtosis Statistic
Items related to effectiveness of team learning:								
KAcq1	278	1	5	3.946	0.051	0.859	-0.689	0.359
KAcq2	277	1	5	4.032	0.056	0.930	-1.018	0.960
KAcq3	274	1	5	3.624	0.063	1.045	-0.575	-0.277
KAcq4	275	1	5	3.596	0.062	1.026	-0.518	-0.232
KS1	278	1	5	3.817	0.056	0.938	-0.896	0.774
KS2	278	1	5	3.763	0.061	1.010	-0.612	-0.174
KS3	276	1	5	3.612	0.058	0.971	-0.452	-0.206
KS4	270	1	5	3.648	0.056	0.916	-0.327	-0.153
KS5	277	1	5	3.946	0.056	0.925	-0.667	-0.072
KApp1	278	1	5	3.626	0.058	0.963	-0.679	0.277
KApp2	273	1	5	3.744	0.060	0.996	-0.725	0.191
KApp3	275	1	5	3.895	0.057	0.947	-0.695	0.007
KApp4	268	1	5	3.784	0.0.63	1.034	-0.703	-0.008
KApp5	260	1	5	3.688	0.0.65	1.043	-0.644	-0.022
KApp6	277	2	5	3.791	0.058	0.959	-0.786	0.554
Items related to team integration:								
IFun1	277	1	5	3.578	0.052	0.863	-0.463	0.306
IFun2	277	1	5	3.520	0.054	0.903	-0.505	0.344
IFun3	277	1	5	3.899	0.054	0.903	-0.899	0.888
INorm1	277	1	5	3.801	0.056	0.925	-0.591	0.089
INorm2	277	1	5	3.801	0.059	0.974	-0.610	-0.061
INorm3	277	1	5	3.744	0.061	1.012	-0.672	0.115
INorm4	278	1	5	3.817	0.058	0.961	-0.806	0.488
INorm5	268	1	5	3.705	0.057	0.940	-0.390	-0.336
ISoc1	275	1	5	3.876	0.054	0.892	-0.813	0.819
ISoc2	263	1	5	3.517	0.063	1.026	-0.378	-0.339
ISoc3	275	1	5	3.629	0.057	0.948	-0.466	-0.042
ISoc4	278	1	5	3.874	0.057	0.947	-0.798	0.610
ISoc5	275	1	5	3.680	0.060	0.996	-0.484	-0.260
Items related to new product development performance:								
Quality1	272	1	5	3.643	0.060	0.995	-0.368	-0.254
Quality2	264	1	5	3.693	0.065	1.050	-0.570	-0.128
Quality3	252	1	5	3.659	0.070	1.112	-0.571	-0.394
Time1	272	1	5	2.640	0.067	1.108	0.209	-0.605
Time2	260	1	5	3.119	0.068	1.096	-0.132	-0.547
Cost1	260	1	5	2.858	0.061	0.990	0.073	-0.127
Cost2	249	1	5	2.996	0.065	1.022	-0.038	-0.238

* See Appendix F for a description of the items.

Kurtosis is a measure of the extent to which observations cluster around a central point. For a normal distribution, the value of the kurtosis statistic is 0. Positive kurtosis indicates that the observations cluster more and have longer tails than those in the normal distribution and negative kurtosis indicates that he observations cluster less and have shorter tails. Excessive kurtosis occurs when test values are outside the range of -7 t0 +7. The results showed that data are not displaying excessive kurtosis and it can be concluded that they met the requirement for normality.

6.3 Measurement Model Assessment

The next stage of the research involved assessment of the measurement scales. The objective of this stage was to ensure that the measurement instruments are valid and reliable in order to guarantee that they constitute good measures of the constructs in the model. Analysis of the measurement instruments is recommended for two main reasons: it provides confidence that the empirical findings accurately reflect the proposed constructs and allows to use the empirically validated scales in other studies (Ahire *et al.*, 1996). Scale validation is critical especially for newly developed constructs, such as the construct of the Internet-based technology use proposed in this thesis. It is also important for constructs that were modified and adapted for a given research, which in the case of this study include communication quality, effectiveness of team learning, team integration, and NPD performance.

The evaluation of the measures and their corresponding constructs for the purpose of this thesis was performed before the actual testing of the structural model and hypotheses. This approach is consistent with the two-step procedure recommended by Anderson and Gerbing (1988).

6.3.1 Construct Validity and Unidimensionality

Validity is the extent to which a set of measures correctly represents the concept of study. Two main types of validity are important in the context of this study: *content validity* and *construct validity*. *Content validity* is based on the extent to which a measurement reflects the specific intended domain of content (Carmines and Zeller, 1979). In general, an instrument is considered to have content validity if there is a general agreement in the literature that the instrument covers all aspects of the construct being measured (Churchill, 1979).

Davis (1996) recommended the following four step procedure to ensure content validity: conduct an exhaustive search of the literature for all possible items to be included in the scale; solicit expert opinions on the inclusion of items; pretest the scale on a set of respondents similar to the population to be studied; and modify as necessary. Since selection of the measurement items in this study was based on the extensive review of literature and they were verified and pre-tested by a group of experts in the area, the measures proposed can be considered to have content validity under the Carmines and Zeller (1979) and Churchill (1979) criteria.

Construct validity is the extent to which an observation measures the concept it purports to measure (Carmines and Zeller, 1979). Construct validity is therefore evidenced by the degree that a particular indicator measures what it is supposed to measure rather than reflecting some other phenomenon. Cronbach and Meehl (1955) recommended that construct validity be tested in every study, since there are no indicators commonly accepted as entirely adequate to measure a given construct. To ensure construct validity, measures should have *convergent validity* and *discriminant validity.*

Convergent validity refers to the extent to which multiple measures of a construct are in agreement (Campbell and Fiske, 1959). Churchill (1979) asserted that "evidence of the convergent validity of the measure is provided by the extent to which it correlates highly with other methods designed to measure the same construct". If two or more measures are true indicators of a concept, then they should necessarily be highly correlated. Failure to find high correlation among multiple measures of a construct would imply that either the measures are poor or the construct and the measures do not correspond with each other (Bagozzi and Phillips, 1980). *Discriminate validity*, on the other hand, measures the degree to which a theoretical construct in a theoretical model differs from other constructs in the same model (Campbell and Fiske, 1959). Discriminate validity is therefore achieved when measures of different constructs share little common variance.

Unidimensionality is defined as the existence of one latent trait or construct underlying a set of measures (Hattie, 1985; McDonald, 1981). The construct of interest may correspond either to a first-order factor, or to a second- or higher order factor (Gerbing and Anderson, 1984). Anderson and Gerbing (1982) introduced the criteria of internal consistency and external consistency, each representing a necessary condition for unidimensional measurement. In order to assess validity and unidimensionality for the purpose of this thesis, confirmatory factor analysis of a multiple-indicator factor model was employed, as recommended by Anderson and Gerbing (1982). The advantage of this approach is that the full-information estimation methods (e.g., Bentler, 1983; Joreskog, 1969, 1978) for the confirmatory factor model jointly assume internal consistency and external consistency for any specified model to arrive at parameter estimates. As a result, assessment of the measurement model provided by CFA in the form of different goodness-of-fit indices represents a sufficient condition for unidimensional measurement. (Anderson *et al.*, 1987).

Five confirmatory measurement models were estimated in order to evaluate the measurement scales used in this study, one for each of the constructs: Internet-based technologies use, communication quality, effectiveness of team learning, team integration and NPD performance. The following sections describe the fit and characteristics of measurement models for each of these constructs. For each measurement model, three groups of results are reported: loadings between each measurement item and its corresponding construct; the overall fit indices of the measurement model; and explanation and results of model modification, if it took place. After the discussion of the measurement models testing results, the findings are summarized in Table 6.2.

6.3.1.1 Internet-Based Technology Use

The construct of Internet-based technology use was conceptualized as a multi-dimensional construct consisting of the following four dimensions: Internet-based technology use for data and information management; Internet-based technology use for collaborative team work; Internet-based technology use for external partner/supplier/ customer involvement; and Internet-based technology use for project management and control. These dimensions were measured, respectively, with: 5 items (IBT_A1 – IBT_A5), 4 items (IBT_B1 – IBT_B4), 4 items (IBT_C1 – IBT_C4), and 5 items (IBT_D1 – IBT_D5). All the items are described in Appendix F.

Confirmatory factor analysis of the hypothesized measurement model of Internet-based technology use indicated poor fit to data (chi-square = 550.37; df = 131; p-value = 0.000; RMSEA = 0.107; 90% confidence interval for RMSEA=(0.098; 0.12); and p-value for test of close fit (RMSEA<0.05) = 0). As a result of analysis of modification indexes, residuals and loadings' significance levels, four items were removed in order to improve model fit (item IBT_A2 from the dimension of Internet-based technology use for data and information management; item IBT_B4 form the dimension of Internet-based technology use for collaborative team work; item IBT_C4 from the dimension of Internet-based technology use for external partner/supplier/customer involvement; and item IBT_D2 from the dimension of Internet-based technology use for project management and control. The respecified model was next estimated. The resulting standardized item loadings and measurement errors are presented in Figure 6.1.

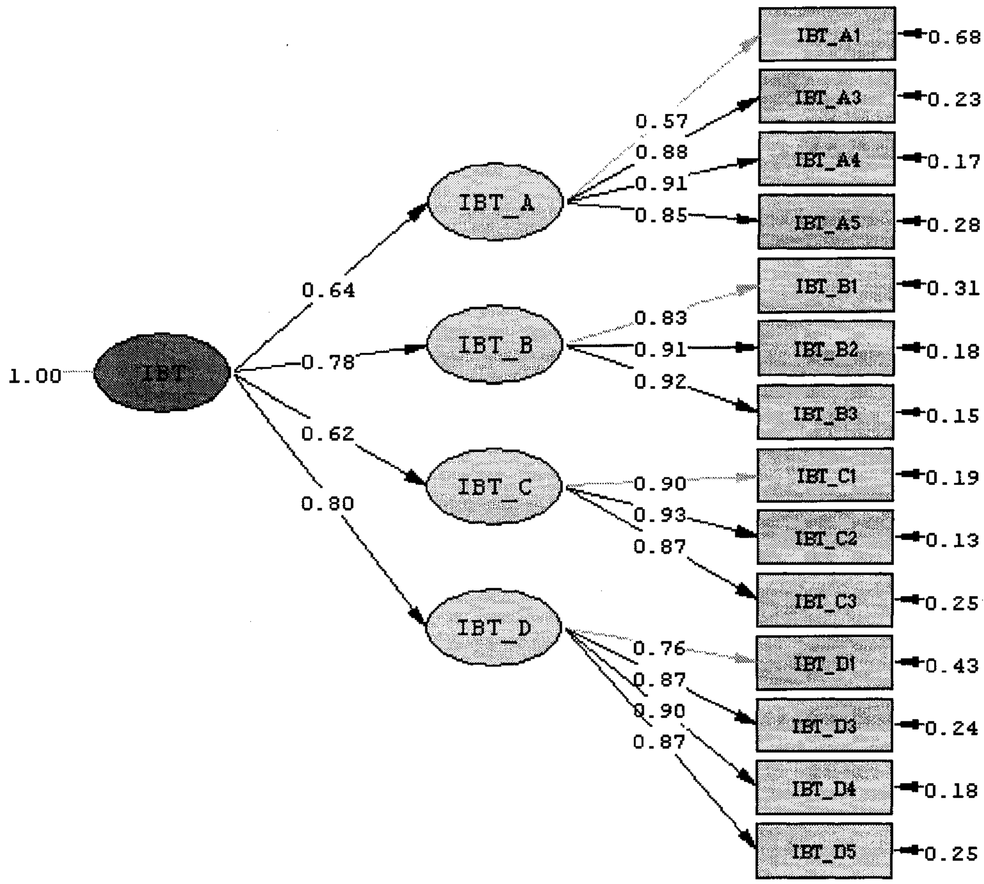


Figure 6.1 Measurement model of Internet-based technology use

The purification of the measurement model for Internet-based technology use led to significant improvement of the model fit: model chi-square statistic changed from 550.37 (with 131 degrees of freedom) to 161.38 (with 73 degrees of freedom); p-value = 0 and the model RMSEA changed from 0.107 to 0.066. The resulting 90% confidence interval for RMSEA is (0.052; 0.080) while p-value for test of close fit (RMSEA < 0.05) equals 0.03. The modified measurement model of Internet-based technology use indicates moderate fit to data allowing it to be used in the testing of the structural model.

6.3.1.2 <u>*Communication Quality*</u>

The second measurement model analyzed in this thesis is the measurement model of communication quality. Communication quality was conceptualized as a one-dimensional construct and was measured with five items (CQ1-CQ5, see Appendix F for item descriptions). The initial measurement model of communication quality showed poor fit to data (chi-square = 20.72 with 5 degrees of freedom; p-value = 0.00091; RMSEA = 0.107; 90% confidence interval for RMSEA = (0.062; 0.16); and p-value for test of close fit (RMSEA<0.05) = 0.022). Further analysis indicated that the poor fit was caused by two indicators (CQ1 and CQ2) with highly autocorrelated errors. Removal of one of them (CQ2, based on the analysis of residuals, modification indexes and item correlations) substantially improved the model fit and resulted in a measurement model of communication quality characterized by high validity. The modified model of communication quality (with its standardized item loadings and measurement errors) is presented in Figure 6.2.

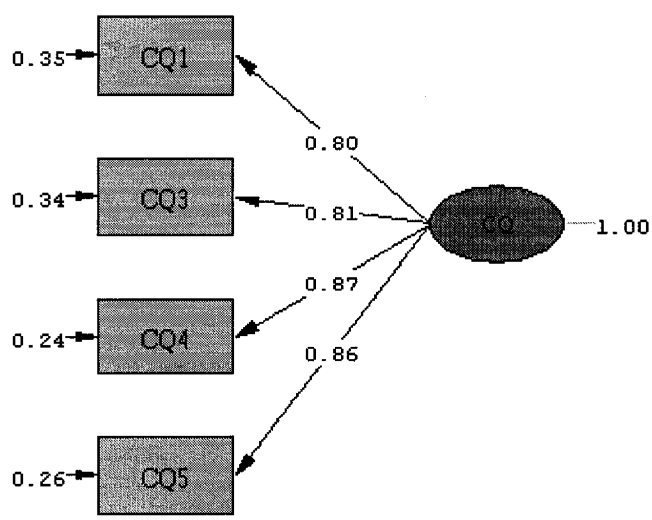


Figure 6.2 Measurement model of communication quality

The final model of communication quality has a very good fit to the data: chi-square = 2.14 with 2 degrees of freedom (as compared to original chi-square of 20.72 with 5 degrees of freedom); p-value = 0.3428; RMSEA = 0.016; 90% confidence interval for RMSEA = (0.0; 0.12) and p-value for test of close fit (RMSEA<0.05) = 0.56.

6.3.1.3 Effectiveness of Team Learning

The third measurement model proposed in this thesis examined the relationships among measures of effectiveness of team learning (15 items: KAcq1 – KAcq4; KS1 – KS5; KApp1 – KApp6; see Appendix F for a detailed description). Effectiveness of team learning was conceptualized as consisting of three dimensions: effectiveness of information acquisition (measured with items: KAcq1 – KAcq4), effectiveness of knowledge sharing (measured with items: KS1 – KS5); and effectiveness of knowledge application (measured with items: KApp1 – KApp6).

As the previous models, the original measurement model of effectiveness of team learning was estimated using confirmatory factor approach within SEM methodology. The resulting standardized loadings ranged from 0.62 to 0.83; chi-square was equal to 279.37 (with 87 degrees of freedom) and RMSEA was equal to 0.089. The 90% confidence interval for RMSEA was (0.078; 0.10), while the probability of RMSEA being less than 0.05 (test of close fit) was equal to 0. These results indicate poor fit of the model to the data which could be improved. Analysis of the modification indexes as well as of correlations between the items constituting the measures of effectiveness of team learning, suggested removal of the following four items: KAcq4, KS3, KS5, and KApp1 in order to improve model fit. The re-specified measurement model was again estimated. The resulting structure of the effectiveness of team learning construct, together with the standardized loadings of the 11 items that remained in the model and measurement errors is presented in Figure 6.3.

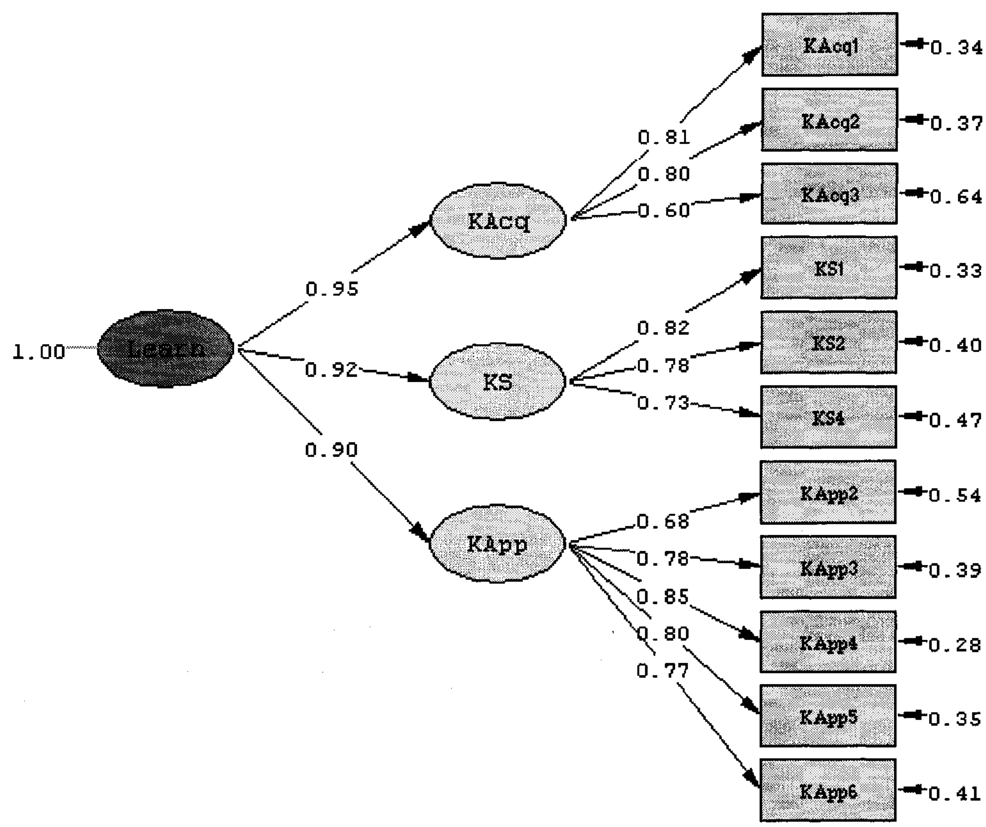


Figure 6.3 Measurement model of effectiveness of team learning

This re-specification of the model led to significant improvement in the fit indices (chi-square = 73.87 with 41 degrees of freedom; p-value = 0.00124; RMSEA = 0.054). As a result of the changes, the new 90% confidence interval for RMSEA is (0.033; 0.073) and the p-value for test of close fit is 0.36.

6.3.1.4 Team Integration

The next measurement model analyzed in this thesis examines the relationships among measures of team integration. Team integration was hypothesized to consist of three dimensions, namely: functional integration, normative integration, and social integration. The three dimensions were measured with 13 items in total (functional integration was measured with 3 items: IFun1 – IFun3; normative integration was measured with 5 items: INorm1 – INorm5; and social integration was measured with 5 items: ISoc1 – ISoc5, see Appendix F for their detailed description).

The hypothesized measurement model was estimated with FIML method and yielded a chi-square of 147.46 with 62 degrees of freedom (p-value = 0.0) and RMSEA equal to 0.070 (90% confidence interval for RMSEA = (0.056; 0.085); p-value for test of close fit (RMSEA < 0.05) = 0.012). Again, these result indicate poor model fit to the data, and the further analysis of modification indices suggested that a significant model improvement can be achieved by removal of two items: IFun3 and ISoc2. The modified measurement model of team integration was then estimated and the obtained results are presented in Figure 6.4.

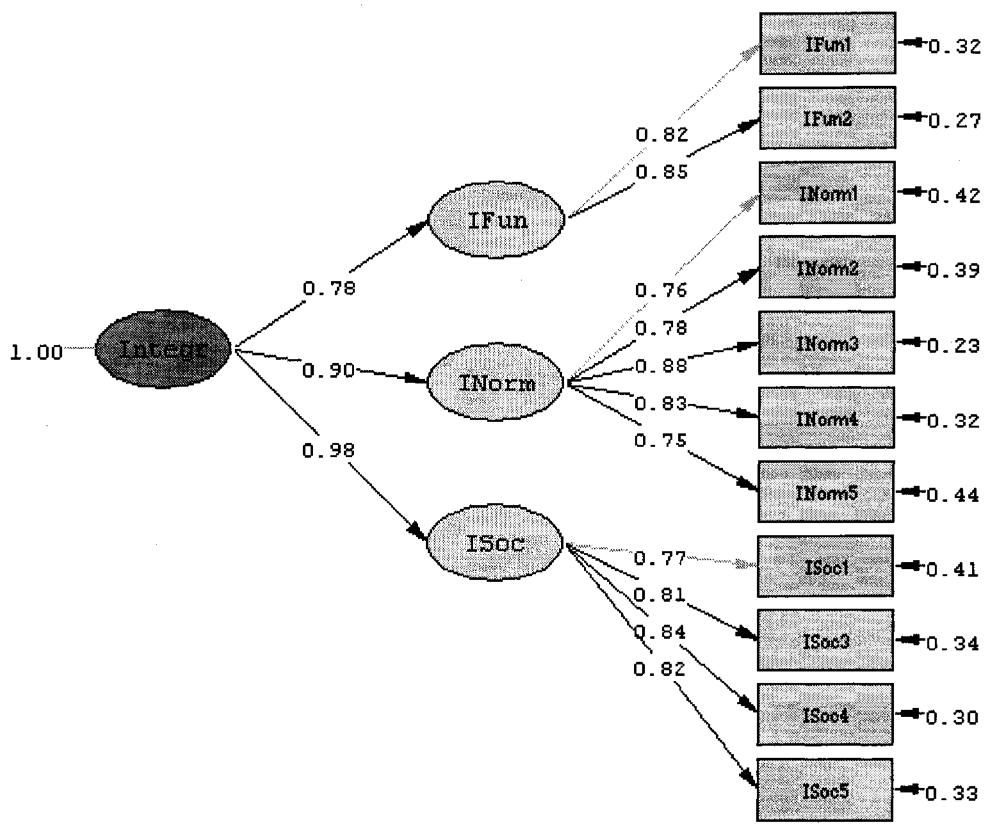


Figure 6.4 Measurement model of team integration

The standardized item loadings of the 11 items that remained in the model range from 69 to 89. The model fit is greatly improved, with chi-square of 59.78 (with 41 degrees of freedom) and p-value equal to 0.0292. The new value of RMSEA is 0.041, while 90% confidence interval for RMSEA is (0.013; 0.062) and p-value for test of close fit is 0.75.

6.3.1.5 <u>NPD Performance</u>

The last measurement model investigated in this thesis examined the relationships among measures of new product development performance. NPD performance was conceptualized as a three-dimensional construct consisting of the following dimensions: product quality, time-to-market and development cost. Each of these dimensions was measured with three items (product quality was measured with items Quality1 – Quality3; time-to-market was measured with items Time1 – Time3; and development cost was measured with items Cost1 – Cost3; see Appendix F for their description).

As it was explained in section on missing data, two of these questions (Time3 and Cost3) were excluded from the analysis, due to high number of missing values. Estimation of the initial measurement model of NPD performance (after removal of Time3 and Cost3) indicated its serious lack of fit: chi-square of 51.22 with 11 degrees of freedom (p-value = 0.0) and RMSEA equal to 0.115 (90% confidence interval for RMSEA = (0.084; 0.15); and p-value for test of close fit (RMSEA < 0.05) = 0.0).

Analysis of modification indexes, residuals, standardized item loadings and the items themselves indicated lack of a way to improve the fit of the three-dimensional model of NPD performance. Similar questions across different dimensions (quality as compared to previous projects, time-to-market as compared to previous projects, and development cost as compared to previous projects) have autocorrelated measurement errors and there is no method to overcome it, other than conducting a separate analysis for each of the three dimensions of NPD performance.

As a result, a decision was made to test the hypothesized structural model separately for each of the initial dimensions of NPD performance. The standardized loadings and measurement errors in measurement model of product quality are presented in Figure 6.5. Given that this model is just identified, its fit is perfect. Models of time-to-market and development cost could not be estimated, because they are underidentified.

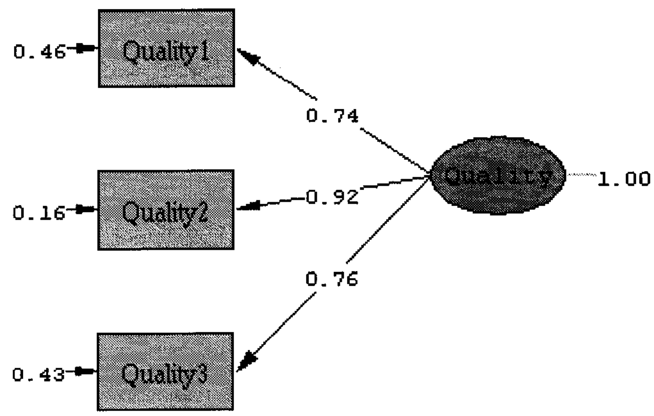


Figure 6.5 Measurement model of product quality

In summary, all the constructs and sub-constructs (except for NPD performance) in the study, after respecification, achieved a moderate to high level of construct validity. However, it was impossible to develop a valid measurement model for NPD performance. A summary of the fit statistics of all the initially hypothesized measurement models and the respecified models are shown in Table 6.2.

Table 6.2 Summary of the results of confirmatory factor analysis

	χ^2	df	P-value	RMSEA	90% confidence interval for RMSEA	P-value for test of close fit (RMSEA<0.05)
INITIAL MEASUREMENT MODELS						
Internet-based technology use	550.37	131	0.0	0.107	(0.098; 0.12)	0.0
Communication quality	20.72	5	0.0	0.107	(0.062; 0.16)	0.022
Effectiveness of team learning	279.37	87	0.0	0.089	(0.078; 0.10)	0.0
Team integration	147.46	62	0.0	0.070	(0.056; 0.085)	0.012
NPD Performance	51.22	11	0.0	0.115	(0.084; 0.15)	0.0
RESPECIFIED MEASUREMENT MODELS						
Internet-based technology use	161.38	73	0.0	0.066	(0.052; 0.080)	0.03
Communication quality	2.14	2	0.343	0.016	(0.0; 0.12)	0.56
Effectiveness of team learning	73.87	41	0.0012	0.054	(0.033; 0.073)	0.36
Team integration	59.78	41	0.03	0.041	(0.013; 0.062)	0.75

6.3.2 Reliability

Unidimensionality alone is not sufficient to ensure the usefulness of a scale. Gerbing and Anderson (1988) argued that the reliability of the composite score should be assessed after unidimensionality has been acceptably established. They pointed out that “even a perfectly unidimensional (and otherwise construct valid) scale would be of little or no practical use of the resultant composite scores were determined primarily by measurement error, with the values of the scores widely fluctuating over repeated measurements”. *Reliability* refers to the ability to achieve identical or similar outputs by the repeated use of the technical instruments for data collection (Roy *et al.*, 2003). Reliability analysis therefore investigates the degree of consistency in a measuring instrument (Carmines and Zeller, 1979).

Traditional way of assessing the reliability of constructs involves computation of the Cronbach's alpha coefficient (Cronbach, 1951; 1971). However, recent studies show its limitations and recommend confirmatory factor analysis and computation of composite reliability as the proper means of verifying measures reliability (Gerbing and Anderson, 1988). Cronbach alpha in most cases is only a lower bound on reliability (Bollen, 1989) and when it is computed for items with unequal reliabilities it will lead to the underestimation of the reliability of the composite score (Smith, 1974). A better choice is composite reliability, which draws on the standardized loadings and measurement error for each item. A popular rule of thumb is that 0.70 is an acceptable threshold for composite reliability, with each indicator reliability recommended to be above 0.50 (Fornell and Larcker, 1981).

From classical test theory, the reliability (ρ_{yT}) of a single measurement y is:

$$\rho_{yT} = \frac{Var(T)}{Var(T) + Var(\varepsilon)} = 1 - \frac{Var(\varepsilon)}{Var(y)} \qquad (4)$$

T is the underlying true score and ε is the error of measurement. If all variables have zero expectation, the true score is independent of measurement error and individual measurement errors are independent, the reliability (convergent validity) of each measure y in a single factor model can be shown to be:

$$\rho_y = \frac{\lambda_y^2}{\lambda_y^2 + Var(\varepsilon_y)} \tag{5}$$

The reliability (internal consistency) for the construct η is:

$$\rho_\eta = \frac{\left(\sum_{i=1}^{p} \lambda_{yi}\right)^2}{\left(\sum_{i=1}^{p} \lambda_{yi}\right)^2 + \sum_{i=1}^{p} Var(\varepsilon_i)} \tag{6}$$

Though ρ_y indicates the reliability of a single measure and ρ_η the reliability of the construct, neither one measures the amount of variance that is captured by the construct in relation to the amount of variance due to measurement error. The average variance extracted $\rho_{vc(\eta)}$ provides this information and can be calculated as:

$$\rho_{vc(\eta)} = \frac{\sum_{i=1}^{p} \lambda_{yi}^2}{\sum_{i=1}^{p} \lambda_{yi}^2 + \sum_{i=1}^{p} Var(\varepsilon_i)} \tag{7}$$

If $\rho_{vc(\eta)}$ is less than .50, the variance due to measurement error is larger than the variance captured by the construct η, and the validity of the individual indicators (y_i), as well as the construct (η), is questionable. The reliability for each measure x (ρ_x), for the construct ξ (ρ_ξ), and for the average variance extracted ($\rho_{vc(\xi)}$) can be developed in analogous manner. It is important to assess both the composite reliability and variance extracted. On the basis of ρ_η alone, the researcher may conclude that the convergent validity of the construct is adequate, even though more than 50% of the variance is due to error. The calculations of indicator reliability, composite reliability and average variance extracted for the data analyzed in this thesis are reported in Table 6.3.

Table 6.3 Scales and associated indicators: reliability

Item*	Loading	Error variance	Indicator reliability	Construct reliability
IBT USE FOR DATA AND INFORMATION MANAGEMENT				
IBT_A1	0.57	0.68	0.32	ρ = 0.883 VE = 0.66
IBT_A3	0.88	0.23	0.77	
IBT_A4	0.91	0.17	0.83	
IBT_A5	0.85	0.28	0.72	
IBT USE FOR COLLABORATIVE TEAMWORK				
IBT_B1	0.83	0.31	0.69	ρ = 0.917 VE = 0.79
IBT_B2	0.91	0.18	0.83	
IBT_B3	0.92	0.15	0.85	
IBT USE FOR EXTERNAL PARTNER INVOLVEMENT				
IBT_C1	0.90	0.19	0.81	ρ = 0.927 VE = 0.81
IBT_C2	0.93	0.13	0.86	
IBT_C3	0.87	0.25	0.76	
IBT USE FOR PROJECT MANAGEMENT				
IBT_D1	0.76	0.43	0.58	ρ = 0.913 VE = 0.728
IBT_D3	0.87	0.24	0.76	
IBT_D4	0.90	0.18	0.81	
IBT_D5	0.87	0.25	0.76	
INTERNET-BASED TECHNOLOGY USE				
IBT_A	0.64	0.59	0.41	ρ = 0.81 VE = 0.513
IBT_B	0.78	0.39	0.61	
IBT_C	0.62	0.61	0.39	
IBT_D	0.80	0.36	0.64	
COMMUNICATION QUALITY				
CQ1	0.80	0.35	0.64	ρ = 0.904 VE = 0.70
CQ3	0.81	0.34	0.66	
CQ4	0.87	0.24	0.76	
CQ5	0.86	0.26	0.74	
INFORMATION ACQUISITION				
KAcq1	0.81	0.34	0.66	ρ = 0.783 VE = 0.553
KAcq2	0.80	0.37	0.64	
KAcq3	0.60	0.64	0.36	
KNOWLEDGE SHARING				
KS1	0.82	0.33	0.67	ρ = 0.819 VE = 0.603
KS2	0.78	0.40	0.61	
KS4	0.73	0.47	0.53	

Item*	Loading	Error variance	Indicator reliability	Construct reliability
KNOWLEDGE APPLICATION				
KApp2	0.68	0.54	0.46	ρ = 0.884 VE = 0.604
KApp3	0.78	0.39	0.61	
KApp4	0.85	0.28	0.72	
KApp5	0.80	0.35	0.64	
KApp6	0.77	0.41	0.59	
EFFECTIVENESS OF TEAM LEARNING				
KAcq	0.95	0.10	0.90	ρ = 0.946 VE =0.853
KS	0.92	0.15	0.85	
KApp	0.90	0.19	0.81	
FUNCTIONAL INTEGRATION				
IFun1	0.82	0.32	0.67	ρ = 0.825 VE = 0.695
IFun2	0.85	0.27	0.72	
NORMATIVE INTEGRATION				
INorm1	0.76	0.42	0.58	ρ = 0.899 VE = 0.642
INorm2	0.78	0.39	0.61	
INorm3	0.88	0.23	0.77	
INorm4	0.83	0.32	0.69	
INorm5	0.75	0.44	0.56	
SOCIAL INTEGRATION				
ISoc1	0.77	0.41	0.59	ρ = 0.884 VE = 0.658
ISoc3	0.81	0.34	0.66	
ISoc4	0.84	0.30	0.71	
ISoc5	0.82	0.33	0.67	
TEAM INTEGRATION				
IFun	0.78	0.39	0.61	ρ = 0.919 VE = 0.793
INorm	0.90	0.19	0.81	
ISoc	0.98	0.04	0.96	
PRODUCT QUALITY				
Quality1	0.74	0.46	0.55	ρ = 0.811 VE = 0.593
Quality2	0.84	0.29	0.71	
Quality3	0.72	0.48	0.52	
TIME-TO-MARKET				
Time1	0.77	0.41	0.59	ρ = 0.757 VE = 0.605
Time2	0.79	0.37	0.62	
DEVELOPMENT COST				
Cost1	0.83	0.32	0.69	ρ = 0.785 VE = 0.65
Cost2	0.78	0.39	0.61	

* See Appendix F for a description of the items.

Analysis of the results indicates that for the constructs considered in this thesis, the values of composite reliability as well as average variance extracted are greater that the recommended thresholds of 0.70 and 0.50 respectively. Each of the items contributes to the formation of only one dimension and to no other. All standardized loadings presented in Figures 6.1-6.5 were significant at $p<0.01$, indicating that the items did adequately reflect their corresponding constructs. These results suggest that all the theoretical constructs analyzed exhibit good psychometric properties.

6.3.3 Discriminant Validity

Discriminant validity can also be tested using an approach proposed by Fornell and Larcker (1981) and Hulland (1999). Fornell and Larcker (1981) suggested that the shared variance between any two constructs should be less than the variance extracted by either of the individual constructs. In other words, the values on the diagonal of the correlation matrix presented in Table 6.4 should be greater than the corresponding values in each row and column. Analysis of the measurement scales indicated significant improvement in the quality of the measurement models obtained through their respecification and purification of the items. The final measurement models provide a highly reliable and valid measurement of the constructs considered in this study. Therefore, the modified measurement models were included in the analysis of structural relationships among the variables of interest.

Table 6.4 Correlation matrix and discriminant validity assessment

	IBT_A	IBT_B	IBT_C	IBT_D	IBT	CQ	IFun	INorm	ISoc	Integr	KAcq	KS	KApp	Learn	Quality	Time	Cost
IBT_A	**0.812**[1]																
IBT_B	0.50	**0.889**															
IBT_C	0.45	0.49	**0.900**														
IBT_D	0.53	0.58	0.52	**0.853**													
IBT	0.67	0.74	0.67	0.78	**0.716**												
CQ	0.22	0.25	0.22	0.26	0.33	**0.837**											
IFun	0.21	0.23	0.21	0.24	0.31	0.53	**0.834**										
INorm	0.24	0.27	0.24	0.28	0.36	0.61	0.73	**0.801**									
ISoc	0.25	0.28	0.25	0.29	0.37	0.63	0.76	0.88	**0.811**								
Integr	0.26	0.29	0.26	0.31	0.39	0.67	0.80	0.92	0.95	**0.891**							
KAcq	0.32	0.35	0.32	0.37	0.47	0.65	0.57	0.65	0.68	0.71	**0.744**						
KS	0.31	0.34	0.31	0.36	0.46	0.64	0.55	0.64	0.66	0.69	0.85	**0.777**					
KApp	0.32	0.35	0.31	0.37	0.47	0.65	0.56	0.65	0.67	0.71	0.87	0.85	**0.777**				
Learn	0.34	0.38	0.34	0.40	0.51	0.70	0.61	0.70	0.72	0.76	0.93	0.91	0.93	**0.924**			
Quality	0.29	0.32	0.29	0.34	0.43	0.52	0.50	0.58	0.60	0.63	0.67	0.66	0.67	0.72	**0.770**		
Time	0.28	0.31	0.28	0.33	0.42	0.31	0.41	0.47	0.49	0.51	0.51	0.50	0.50	0.54	0.55	**0.778**	
Cost	0.22	0.25	0.22	0.26	0.33	0.31	0.42	0.48	0.50	0.52	0.47	0.46	0.47	0.50	0.53	0.87	**0.806**

[1] Fornell and Larcker (1981) measure of discriminant validity which is the square root of the average variance extracted compared to the construct correlations. Bold values are supposed to be greater than those in corresponding rows and columns.

CHAPTER 7

STRUCTURAL EQUATION MODEL ASSESSMENT

The next stage of quantitative analysis involved testing the general fit of the proposed model and the hypothesized relationships. This was done within the framework of structural equation modeling. Given the decision to change the three-dimensional conceptualization of the NPD performance construct to three independent constructs of product quality, time-to-market and development cost, three resulting models (instead of one) were investigated. The following sections describe the analyses that were conducted to test these three models: impact of Internet-based technology use on product quality, impact of Internet-based technology use on time-to-market, and impact of Internet-based technology use on development cost. For each structural model several types of results are reported: standardized path coefficients and their significance levels, standardized factor loadings, model fit statistics, direct, indirect and total effects, suggestions for model respecification and (in cases when it was conducted) results of this respecification.

7.1 Impact of Internet-Based Technology Use on Product Quality

7.1.1 Assessment of Model Fit

The initial model of the impact of Internet-based technology (IBT) use on product quality was created through substitution of product quality in place of NPD performance in the original model presented in Figure 3.1. The remaining constructs present in the structural model were included in the analysis in their revised measurement forms discussed in section 6.3 (i.e. after purification of measurement items). The model was estimated using FIML estimation method. The standardized path coefficients are presented in Figure 7.1.

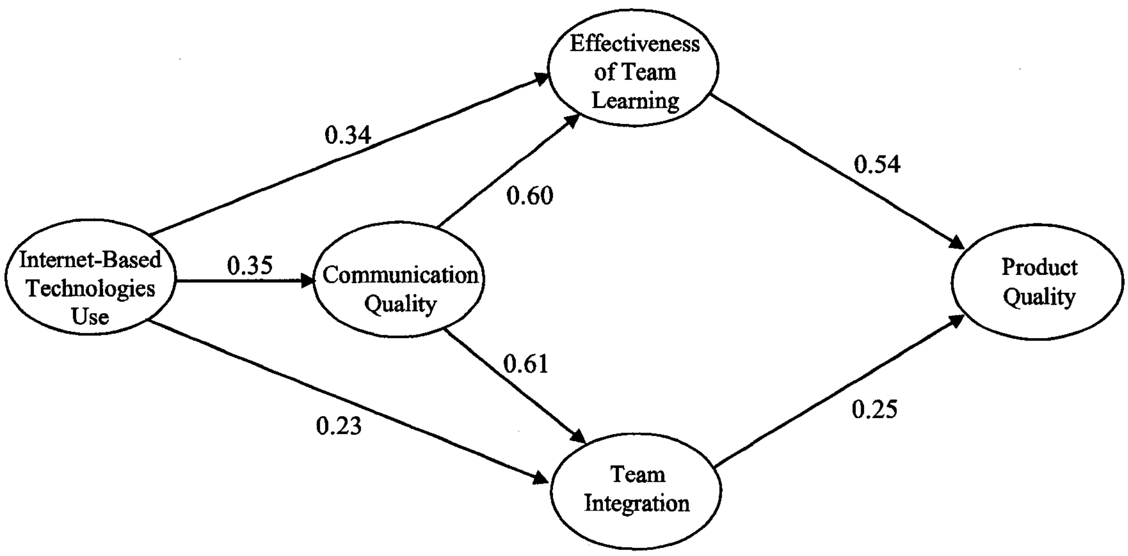


Figure 7.1 Initial structural model of IBT use and product quality

The initial model provided an adequate overall fit to the data. (chi-square = 1195.67 with 843 degrees of freedom; p-value = 0.0; RMSEA = 0.039; 90% confidence interval for RMSEA = (0.034; 0.044); p-value for test of close fit (RMSEA<0.05)=1.00). All hypothesized paths coefficients were significant at α=0.05. However, analysis of standardized residuals indicated large number of residuals (18 residuals) exceeding the value of 2.58, indicating local misspecification of the model.

Investigation of the residuals and modification indices indicated that the model in its initial form, despite an overall good fit to the data, underestimated the strength of the relationship between team integration and effectiveness of team learning. This finding indicated a need for a direct relationship between team integration and effectiveness of team learning, however, it did not determine what the direction of this relationship should be. There were three possible ways of addressing this issue: introduction of a path from team integration to effectiveness of team learning, introduction of a path from effectiveness of team learning to team integration, and introduction of both these paths at the same time (i.e. reciprocal relationship between the two variables of interest).

Although the final decision was made on the grounds of existing theories of teamwork, estimation of all the three models was conducted in order to provide additional understanding of the relationships. The resulting models and standardized path estimates are presented in Figure 7.2 – Figure 7.4 (the dotted lines indicate paths that were not significant at $\alpha = 0.05$).

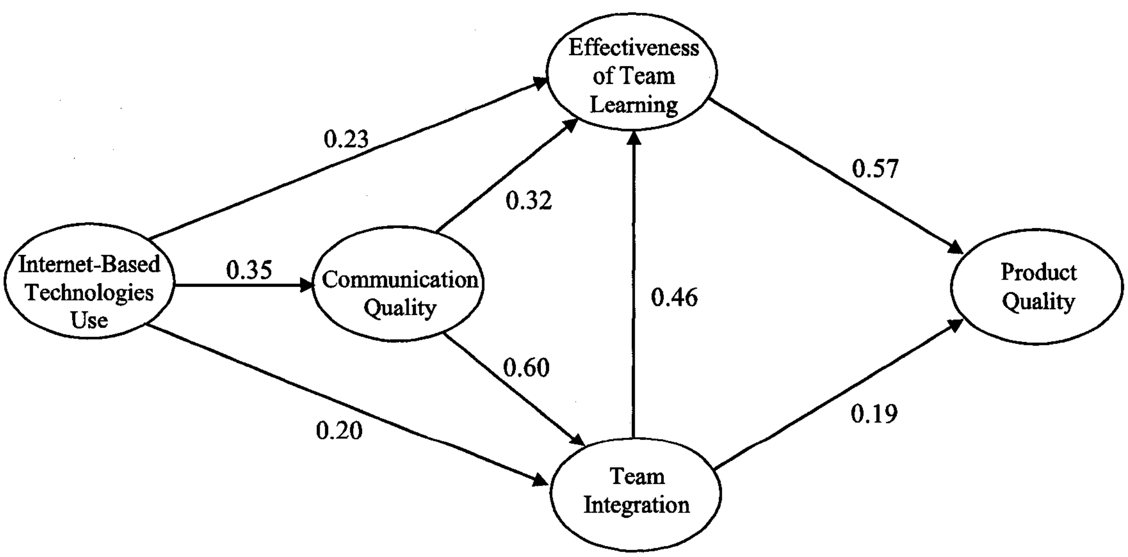


Figure 7.2 Model with a direct path from team integration to effectiveness of team learning

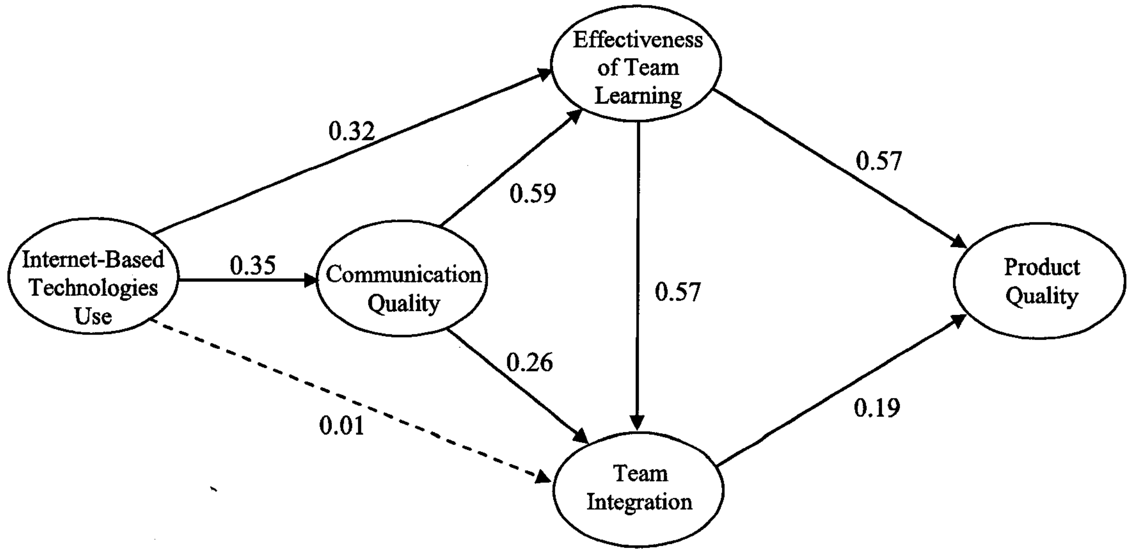


Figure 7.3 Model with a direct path from effectiveness of team learning to team integration

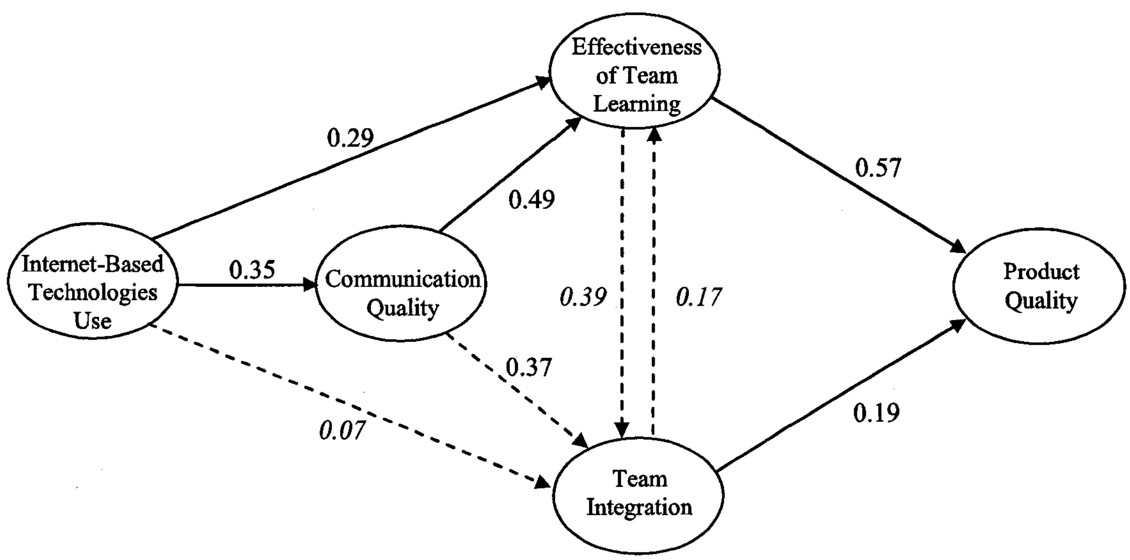


Figure 7.4 Model with a reciprocal relationship between team integration and effectiveness of team learning

All three models provided a very good fit to the data. The fit of all these models is exactly the same, given the fact that they are equivalent models (Bollen, 1989). Their chi-square statistics is equal to 1153.52 with 842 degrees of freedom and RMSEA equals

0.036 (90% confidence interval for RMSEA = (0.031; 0.042); p-value for test of close fit (RMSEA < 0.05) = 1.00). When the values for the new models were compared with the values for model without the direct relationship between team integration and effectiveness of team learning, the significant chi-square difference $\Delta\chi^2(1)=42.15$, $p<0.05$ indicated that the respecified model fits the data significantly better. Further analysis of residuals and chi-square difference statistics indicated that there are no other paths that could significantly improve the model fit.

Out of the three equivalent models, the model with direct path from team integration to effectiveness of team learning was selected for further analysis. This decision was based on the fact that this relationship is very strongly supported in the literature. Although a reciprocal relationship between team integration and effectiveness of team learning also is supported in literature, the model with this reciprocal relationship estimated based on the data collected for this thesis implies lack of significant paths between these two constructs and between IBT use and team integration, what is very unlikely and contradicts existing theories and empirical findings up to date.

As shown, in the final model of the impact of Internet-based technology use on product quality (presented in Figure 7.2) product quality was predicted by both team integration ($\beta=0.19$, $p<0.05$) and effectiveness of team learning ($\beta=0.57$, $p<0.05$). Effectiveness of team learning was predicted by team integration, communication quality and IBT use. Team integration was predicted by communication quality and IBT use. Communication quality was predicted by IBT use. The model explained 53% of the variance in product quality, 69% of the variance in effectiveness of team learning, 48% of the variance in team integration and 12% of the variance in communication quality. All the correlations among all the constructs are presented in Table 7.1 and the factor loadings of the constructs are presented in Table 7.2.

Table 7.1 Correlations among constructs for the final model of product quality

	IBT use	Communication quality	Effectiveness of team learning	Team integration	Product quality
IBT use	1.00				
Communication quality	0.35	1.00			
Effectiveness of team learning	0.53	0.70	1.00		
Team integration	0.40	0.66	0.76	1.00	
Product quality	0.38	0.53	0.72	0.63	1.00

Table 7.2 Standardized factor loadings for the final model of product quality

	IBT use	Communication quality	Effectiveness of team learning	Team integration	Product quality
IBT_A[1]	0.70				
IBT_B[2]	0.71				
IBT_C[3]	0.69				
IBT_D[4]	0.76				
CQ1		0.80			
CQ3		0.82			
CQ4		0.87			
CQ5		0.86			
Information acquisition			0.94		
Knowledge sharing			0.91		
Knowledge application			0.93		
Functional integration				0.79	
Normative integration				0.92	
Social integration				0.96	
Quality1					0.70
Quality2					0.85
Quality3					0.72

[1] Internet-based technology use for data and information management
[2] Internet-based technology use for collaborative team work
[3] Internet-based technology use for external partner/supplier/customer involvement
[4] Internet-based technology use for project management and control

7.1.2 Testing of the Hypotheses

Eight hypotheses regarding the core model (i.e. without considering the moderating variables) were proposed in this study. These hypotheses were reformulated in a way that NPD performance was changed to product quality. They are reviewed below:

Hypothesis 1 Project team integration will positively influence product quality.

Hypothesis 2 Effectiveness of project team learning will positively influence product quality.

Hypothesis 3 Project team communication quality will positively influence project team integration.

Hypothesis 4 Project team communication quality will positively influence effectiveness of project team learning.

Hypothesis 5 The use of Internet-based technologies during a development project will positively influence project team integration.

Hypothesis 6 The use of Internet-based technologies during a development project will positively influence effectiveness of project team learning.

Hypothesis 7 The use of Internet-based technologies during a development project will positively influence project communication quality.

Hypothesis 8 The use of Internet-based technologies during a development project will positively influence product quality.

The hypotheses were examined based on the path coefficients and the total effect sizes among the constructs in the final model of IBT use and product quality described in the previous section. The results of the testing of the hypotheses are summarized in Table 7.3. Hypothesis 1 was supported. Team integration positively influences product quality both directly (there is a significant path coefficient of 0.19 from team integration to product quality) and indirectly, through effectiveness of team learning (standardized indirect effect of 0.26). Similarly, hypothesis 2 is supported: although team learning has only direct effect on product quality, it is significant and equals 0.57. Hypothesis 3 stated positive influence of communication quality on team integration. It was confirmed, as there is a significant direct effect (0.60) between communication quality and team integration. Next, it was hypothesized that communication quality also has a positive influence on team learning (hypothesis 4). This proposition was confirmed as well, and both direct effect (0.32) and indirect effect through team integration (0.27) were identified and were found significant.

Table 7.3 Results of hypotheses testing for the final model of product quality

	Hypothesized sign	Standardized Path Estimates/ Direct Effects	Standardized Indirect Effects	Standardized Total Effects	Result
H1: Team integration → product quality	+	0.19	0.26	0.45	supported
H2: Team learning → product quality	+	0.57	--	0.57	supported
H3: Communication quality→team integr	+	0.60	--	0.60	supported
H4: Communication quality→team learning	+	0.32	0.27	0.59	supported
H5: IBT → team integration	+	0.20	0.21	0.40	supported
H6: IBT → team learning	+	0.23	0.29	0.53	supported
H7: IBT → communication quality	+	0.35	--	0.35	supported
H8: IBT → product quality	+	--	0.38	0.38	supported

Note: All estimates were based on the final model. All estimates are significant at $p < 0.05$

Hypothesis 5 postulated positive influence of IBT use on team integration. Also this hypothesis was confirmed, as again both direct effect of 0.20 and indirect effect of 0.21 (through communication quality) were found significant. Similarly, positive influence of IBT use on effectiveness of team learning (hypothesis 6) was confirmed. There is a direct effect of IBT use on effectiveness of team learning (0.23) and indirect effect as well (0.29). The hypothesis 7, stating positive influence of IBT use on communication quality was supported as well, given the significant path estimate (direct effect) of 0.35 between ITB use and communication quality. The analysis of the findings from the hypotheses testing in the framework of the model of IBT use and product quality indicates a significant role of IBT use in supporting product quality. Although IBT use has only indirect effect on product quality, executed through improvements of communication quality, effectiveness of team learning and team integration, this effect is significant and equals 0.38 in magnitude (confirmed hypothesis 8). Summing up, the model indicates that IBT explains 14.4% of variance in product quality, 12.3% of variance in communication quality, 16% of variance in team integration and 28% of variance in effectiveness of team learning.

7.2 Impact of Internet-Based Technology Use on Time-to-Market

7.2.1 Assessment of Model Fit

The initial model of the impact of Internet-based technology (IBT) use on project time-to-market is similar in its form to the model of the impact of IBT use on product quality investigated in the previous section: the only difference is that the construct of product quality was substituted with the construct of time-to-market. Similarly like before, only the revised measurement models of all the constructs were included in the analysis. Estimation of the model with FIML method yielded the standardized path estimates presented in Figure 7.5.

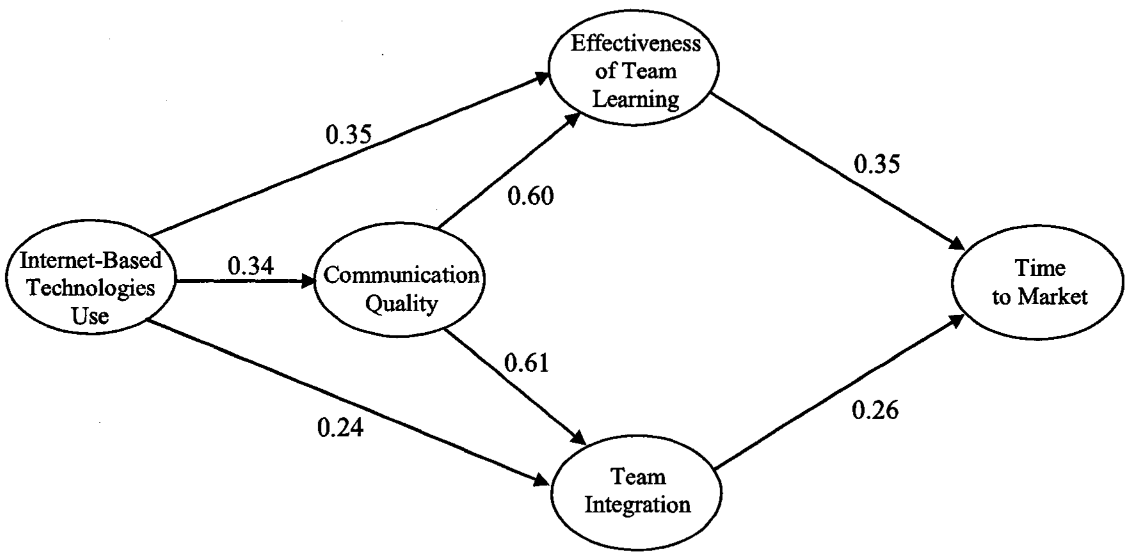


Figure 7.5 Initial structural model of IBT use and time-to-market

Several indices indicated adequate fit of the model to the data (chi-square = 1161.16 with 802 degrees of freedom, p-value = 0.0; RMSEA = 0.040, 90% confidence interval for RMSEA = (0.035; 0.045), p-value for test of close fit (RMSEA < 0.05) = 1.00). All hypothesized paths coefficients were significant. However, the analysis of the standardized residuals indicated presence of 19 residuals exceeding value of 2.58. Similarly like with the model of IBT use and product quality, analysis of residuals indicated a need to add a direct path from team integration to effectiveness of team learning, which was already expected given the results of the analysis of the model of IBT use and product quality. The revised model was estimated and yielded the standardized path coefficients presented in Figure 7.6.

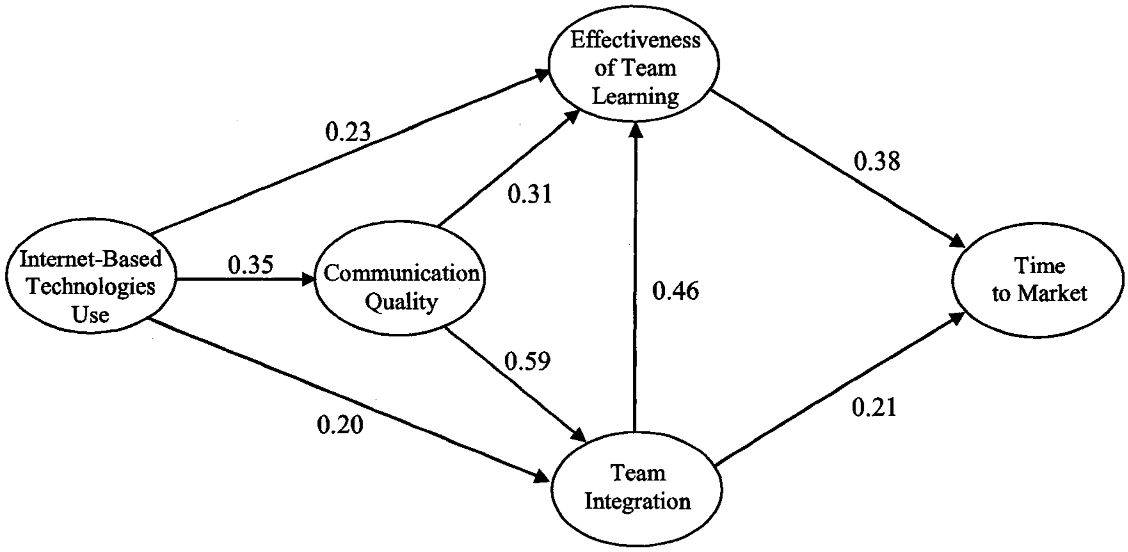


Figure 7.6 Revised structural model of IBT use and time-to-market

The revised model provides a very good fit to the data (chi-square = 1118.34, df = 801, RMSEA = 0.038 (90% confidence interval for RMSEA = (0.032; 0.043); p-value for test of close fit (RMSEA<0.05) = 1.00). When the two models were compared, the significant chi-square difference $\Delta\chi^2(1)=42.82$, $p<0.05$ indicated that the re-specified model fits the data significantly better.

Further analysis of residuals and modification indexes indicated that there might be further significant improvement of the model fit if a direct path from IBT use to time-to-market is added to the model. The chi-square difference test $\Delta\chi^2(1)=5.34$, $p<0.05$ confirmed this observation. The second revised model fits data very well (chi-square = 1113.0 with 800 degrees of freedom, RMSEA = 0.038, 90% confidence interval for RMSEA = (0.032; 0.043); p-value for test of close fit (RMSEA<0.05) = 1.00. Given the significant change in chi-square, the second revised model was chosen as the final model of IBT use impact on time-to-market. The standardized path coefficients for this model are presented in Figure 7.7.

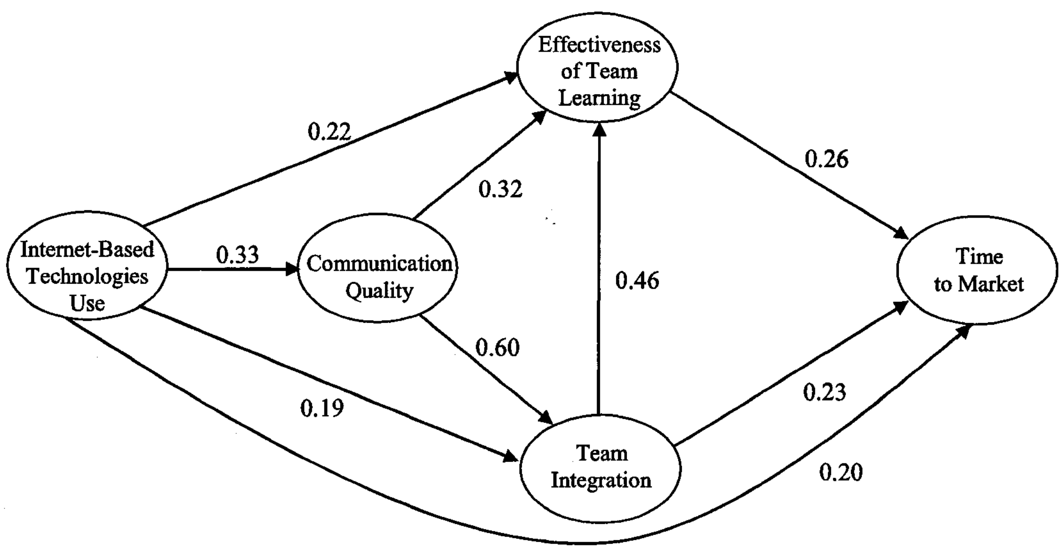


Figure 7.7 Final structural model of IBT use and time-to-market

The final model of the impact of IBT use on time-to-market indicates that project's time-to-market can be predicted by team integration, effectiveness of team learning and IBT use. The relationships among IBT use, communication quality, team integration and effectiveness of team learning did not change significantly as compared to the model of the impact of IBT use on product quality (effectiveness of team learning was predicted by team integration, communication quality and IBT use; team integration was predicted by communication quality and IBT use; communication quality was predicted by IBT use). All the correlations among the constructs are presented in Table 7.4 and the factor loadings of the constructs are presented in Figure 7.5.

Table 7.4 Correlations among constructs for the final model of time-to-market

	IBT use	Communication quality	Effectiveness of team learning	Team integration	Time-to-Market
IBT use	1.00				
Communication quality	0.34	1.00			
Effectiveness of team learning	0.44	0.66	1.00		
Team integration	0.44	0.72	0.68	1.00	
Time-to-Market	0.40	0.41	0.49	0.50	1.00

Table 7.5 Standardized factor loadings for the final model of time-to-market

	IBT use	Communication quality	Effectiveness of team learning	Team integration	Time to Market
IBT_A[1]	0.67				
IBT_B[2]	0.75				
IBT_C[3]	0.66				
IBT_D[4]	0.78				
CQ1		0.80			
CQ3		0.82			
CQ4		0.87			
CQ5		0.86			
Information acquisition			0.93		
Knowledge sharing			0.92		
Knowledge application			0.92		
Functional integration				0.79	
Normative integration				0.92	
Social integration				0.95	
Time1					0.79
Time2					0.76

[1] Internet-based technology use for data and information management
[2] Internet-based technology use for collaborative team work
[3] Internet-based technology use for external partner/supplier/customer involvement
[4] Internet-based technology use for project management and control

The model explains 34% of the variance in time-to-market, 69% of the variance in effectiveness of team learning, 47% of the variance in team integration and 11% of the variance in communication quality.

7.2.2 Testing of the Hypotheses

Again, eight hypotheses regarding the core model were investigated in the context of the relationship between IBT use and development project's time-to-market. These hypotheses were reformulated as follows:

Hypothesis 1 Project team integration will positively influence project's time-to-market.

Hypothesis 2 Effectiveness of project team learning will positively influence project's time-to-market.

Hypothesis 3 Project team communication quality will positively influence project team integration.

Hypothesis 4 Project team communication quality will positively influence effectiveness of project team learning.

Hypothesis 5 The use of Internet-based technologies during a development project will positively influence project team integration.

Hypothesis 6 The use of Internet-based technologies during a development project will positively influence effectiveness of project team learning.

Hypothesis 7 The use of Internet-based technologies during a development project will positively influence project communication quality.

Hypothesis 8 The use of Internet-based technologies during a development project will positively influence project's time-to-market.

The proposed hypotheses were examined based on the path coefficients and their significance levels, as well as based on the total effect sizes among the constructs in the final model of IBT use and project's time-to-market as established in the previous section. The results of the testing of the hypotheses are presented in Table 7.6.

Table 7.6 Results of hypotheses testing for the final model of time-to-market

	Hypothesized sign	Standardized Path Estimates/ Direct Effects	Standardized Indirect Effects	Standardized Total Effects	Result
H1: Team integration → time-to-market	+	0.23	0.12	0.35	supported
H2: Team learning → time-to-market	+	0.26	--	0.26	supported
H3: Communication quality→team integr	+	0.60	--	0.60	supported
H4: Communication quality→team learning	+	0.32	0.28	0.60	supported
H5: IBT → team integration	+	0.19	0.20	0.39	supported
H6: IBT → team learning	+	0.22	0.28	0.51	supported
H7: IBT → communication quality	+	0.33	--	0.33	supported
H8: IBT → time-to-market	+	0.20	0.22	0.42	supported

Note: All estimates were based on the final model. All estimates are significant at $p < 0.05$

Hypothesis 1, stating that team integration positively influences time-to-market was confirmed, with both direct (0.23) and indirect effect (0.12) taking place. Similarly, hypothesis 2, postulating the positive influence of effectiveness of team learning on time-to-market, was also confirmed, with the direct effect of 0.26. When comparing the magnitude of the effects of team integration and effectiveness of team learning on time-to-market with the effects these two variables have on product quality, it becomes visible that in case of product quality team learning is a stronger predictor of product quality than team integration. However, when time-to-market is the dependent variable, team integration has a greater total effect on time-to-market than the effectiveness of team learning.

The next five hypotheses regarding relationships between IBT use, communication quality, team integration and effectiveness of team learning were also confirmed. This result was expected after they were confirmed when the model of IBT use and product quality was tested in section 7.1.2. The relationships did not change significantly and the direct effects and indirect effects are of the same magnitude as described in section 7.1.2. This result was expected, as these relationships should be independent of the choice of dependent NPD performance variable.

The last hypothesis postulated positive impact of IBT use on project's time-to-market. It was confirmed, as the model indicates both direct effect of IBT use on time-to-market (0.20) and indirect effect (0.22). Overall, the total effect of IBT use on time-to-market (0.42) is higher than the total effect of IBT use on product quality. As a result, IBT use explains 18% of the variance in time-to-market, 26% of the variance in effectiveness of team learning, 15% of the variance in team integration and 11% of the variance in communication quality.

7.3 Impact of Internet-Based Technology Use on Development Cost

7.3.1 Assessment of Model Fit

The initial model of IBT use impact on development cost was created through substitution of NPD performance with development time, see Figure 7.8. As in case of the models of IBT use impact on product quality and time-to-market, all the constructs were included in the model in their revised measurement forms. The estimation of the model with FIML method yielded the standardized path coefficients presented in Figure 7.8. All of them were significant.

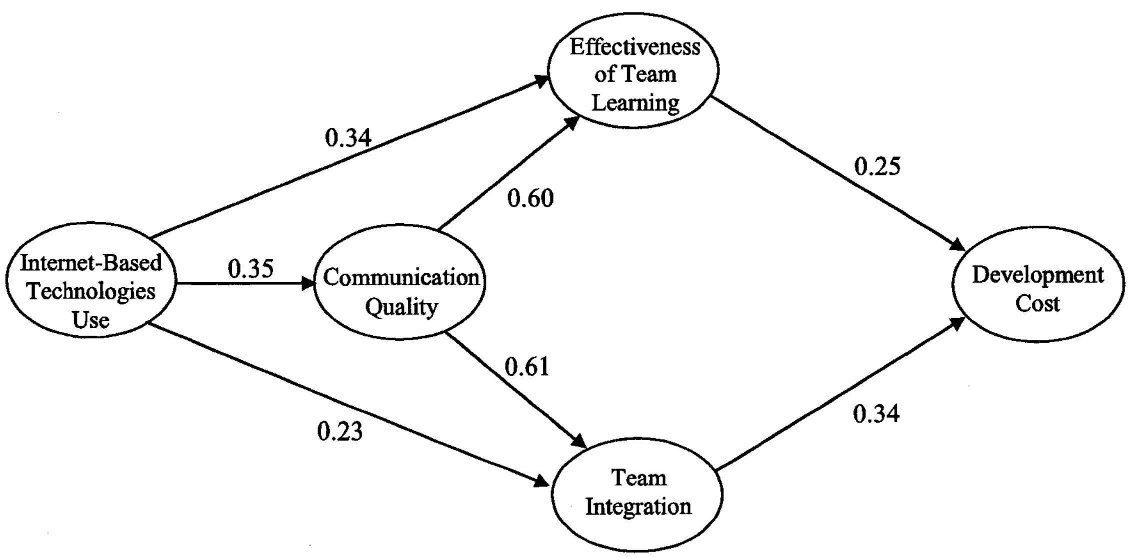


Figure 7.8 Initial structural model of IBT use and development cost

The initial model had good overall fit to the data (chi-square = 1160.77 with 802 degrees of freedom; p-value = 0.0; RMSEA = 0.04; 90% confidence interval for RMSEA was (0.035; 0.045), p-value for test of close fit (RMSEA < 0.05) = 1.00). However, as in the case of the previous models, there was a large number of residuals greater than 2.58 (19 residuals) indicating the need for a path from team integration to effectiveness of team learning. The revised model was estimated and the resulting standardized path coefficients are presented in Figure 7.9.

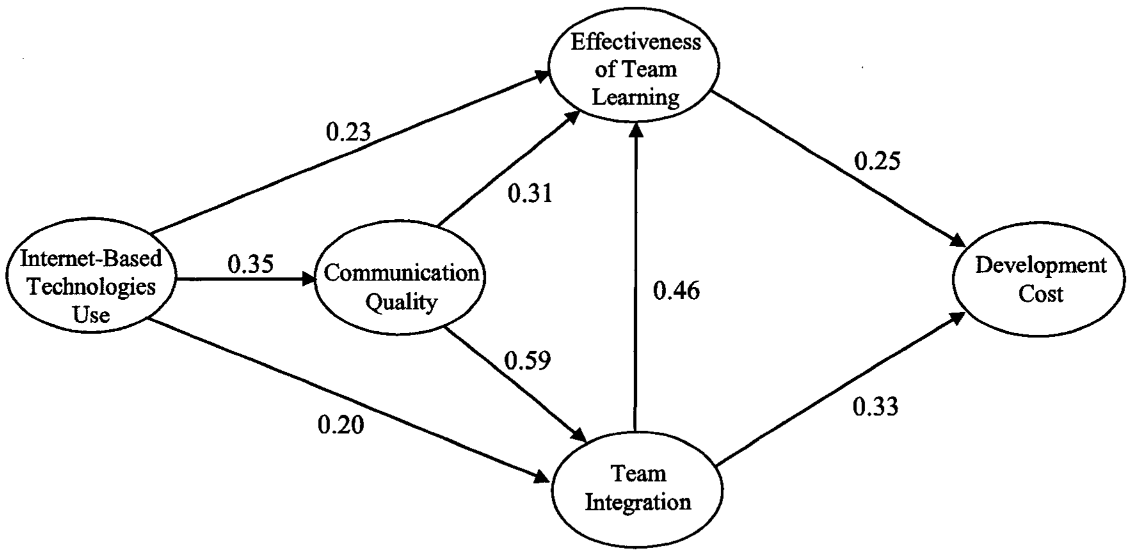


Figure 7.9 Revised structural model of IBT use and development cost

The revised model has a very good fit to the data (chi-square = 1118.14 with 801 degrees of freedom; p-value = 0.0; RMSEA = 0.038; 90% confidence interval for RMSEA = (0.032; 0.043); p-value for test of close fit (RMSEA < 0.05) = 1.00). The significant test of chi-square difference was a basis to keep the revised model as the final model.

The model of the impact of IBT use on development cost indicates that project's development cost can be predicted by team integration and effectiveness of team learning. The relationships among IBT use, communication quality, team integration and effectiveness of team learning already established in the previous two models were reconfirmed as expected. The model explained 30% of the variance in development cost, 69% of the variance in effectiveness of team learning, 47% of the variance in team integration and 12% of the variance in communication quality. All the correlations among all the constructs are presented in Table 7.7 and the factor loadings of the constructs are presented in Table 7.8.

Table 7.7 Correlations among constructs for the final model of development cost

	IBT use	Communication quality	Effectiveness of team learning	Team integration	Development cost
IBT use	1.00				
Communication quality	0.35	1.00			
Effectiveness of team learning	0.52	0.70	1.00		
Team integration	0.40	0.66	0.76	1.00	
Development cost	0.26	0.39	0.50	0.52	1.00

Table 7.8 Standardized factor loadings for the final model of development cost

	IBT use	Communication quality	Effectiveness of team learning	Team integration	Development cost
IBT_A[1]	0.70				
IBT_B[2]	0.72				
IBT_C[3]	0.69				
IBT_D[4]	0.76				
CQ1		0.80			
CQ3		0.82			
CQ4		0.87			
CQ5		0.86			
Information acquisition			0.94		
Knowledge sharing			0.92		
Knowledge application			0.91		
Functional integration				0.80	
Normative integration				0.92	
Social integration				0.96	
Cost1					0.82
Cost2					0.78

[1] Internet-based technology use for data and information management
[2] Internet-based technology use for collaborative team work
[3] Internet-based technology use for external partner/supplier/customer involvement
[4] Internet-based technology use for project management and control

7.3.2 Testing of the Hypotheses

Again, eight hypotheses regarding the core model were investigated in the context of the relationship between IBT use and development cost. These hypotheses were reformulated as follows:

Hypothesis 1 Project team integration will positively influence development cost.

Hypothesis 2 Effectiveness of project team learning will positively influence development cost.

Hypothesis 3 Project team communication quality will positively influence project team integration.

Hypothesis 4 Project team communication quality will positively influence effectiveness of project team learning.

Hypothesis 5 The use of Internet-based technologies during a development project will positively influence project team integration.

Hypothesis 6 The use of Internet-based technologies during a development project will positively influence effectiveness of project team learning.

Hypothesis 7 The use of Internet-based technologies during a development project will positively influence project communication quality.

Hypothesis 8 The use of Internet-based technologies during a development project will positively influence development cost.

The proposed hypotheses were examined based on the path coefficients and their significance levels, as well as based on the total effect sizes among the constructs in the final model of IBT use and development time as established in the previous section. The results of the testing of the hypotheses are presented in Table 7.9.

Hypothesis 1 postulated positive influence of team integration on development cost. The model estimation and testing confirmed this hypothesis: there is both direct (0.33) and indirect effect (0.11) of team integration on development cost. Also hypothesis 2, stating that there is a positive influence of effectiveness of team learning on development cost, was confirmed, with the direct effect of 0.25.

Table 7.9 Results of hypotheses testing for the final model of development cost

	Hypothesized sign	Standardized Path Estimates/ Direct Effects	Standardized Indirect Effects	Standardized Total Effects	Result
H1: Team integration → development cost	+	0.33	0.11	0.45	supported
H2: Team learning → development cost	+	0.25	--	0.25	supported
H3: Communication quality→team integr	+	0.59	--	0.59	supported
H4: Communication quality→team learning	+	0.31	0.27	0.59	supported
H5: IBT → team integration	+	0.20	0.21	0.40	supported
H6: IBT → team learning	+	0.23	0.29	0.52	supported
H7: IBT → communication quality	+	0.35	--	0.35	supported
H8: IBT → development cost	+	--	0.26	0.26	supported

Note: All estimates were based on the final model. All estimates are significant at $p < 0.05$

The next five hypotheses regarding relationships between IBT use, communication quality, team integration and effectiveness of team learning were also confirmed. This result was expected once they were confirmed when the model of IBT use and product quality was tested in section 7.1.2 and then the model of IBT use and time-to-market in

Section 7.2.2. The relationships did not change significantly and the direct effects and indirect effects are of the same magnitude as described in Sections 7.1.2 and 7.2.2. This result was expected, as these relationships should be independent of the choice of independent NPD performance variable. The last hypothesis postulated positive impact of IBT use on development cost. It was confirmed, as the model indicates indirect effect of IBT use on development cost (0.26). As a result, IBT use explains 7% of the variance in development cost.

7.4 Dimensions of Internet-Based Technology Use and NPD Performance

The last stage of structural model analysis focused on different dimensions of Internet-based technology use analyzed not as one construct, but separately. A preliminary investigation was conducted in order to see if there are any differences among the role of different IBT dimensions. Four models were estimated, with product quality as dependent variable, and each of the IBT dimensions as independent variable respectively. The results of model estimation are presented in Figure 7.10 – Figure 7.13.

All four models have a very good fit to data: (Model A: Chi-square = 663.71, df = 481, RMSEA = 0.037; Model B: Chi-square = 637.55, df = 450, RMSEA = 0.039; Model C: Chi-square = 617.30, df = 450, RMSEA = 0.037; Model D: Chi-square = 681.05, df=481, RMSEA = 0.039). Comparison of the obtained path estimated does not reveal any huge differences among the different dimensions of IBT use and their effects on other variables in the model. However, there is a possibility that IBT use for data management and IBT use for external partner involvement may have stronger effect on communication quality than the other two dimensions of IBT. Based on the current analysis this statement cannot be confirmed definitely and should be further investigated.

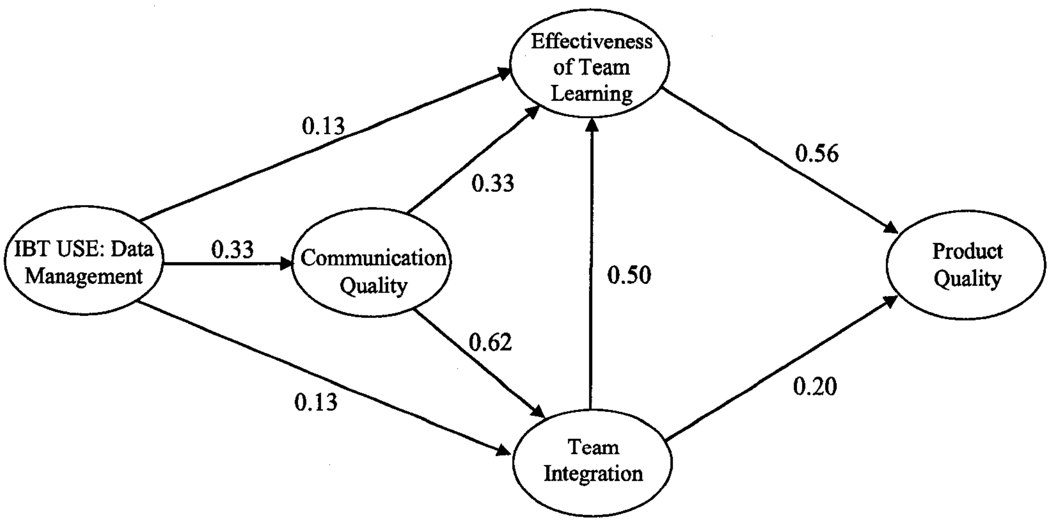


Figure 7.10 Model of the impact of IBT use for data and information management on product quality (Model A)

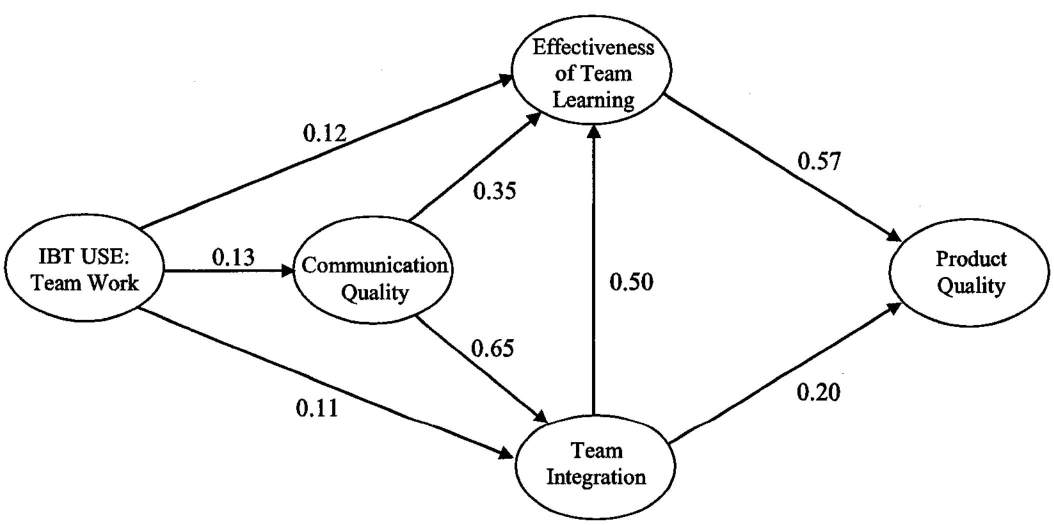


Figure 7.11 Model of the impact of IBT use for collaborative team work on product quality (Model B)

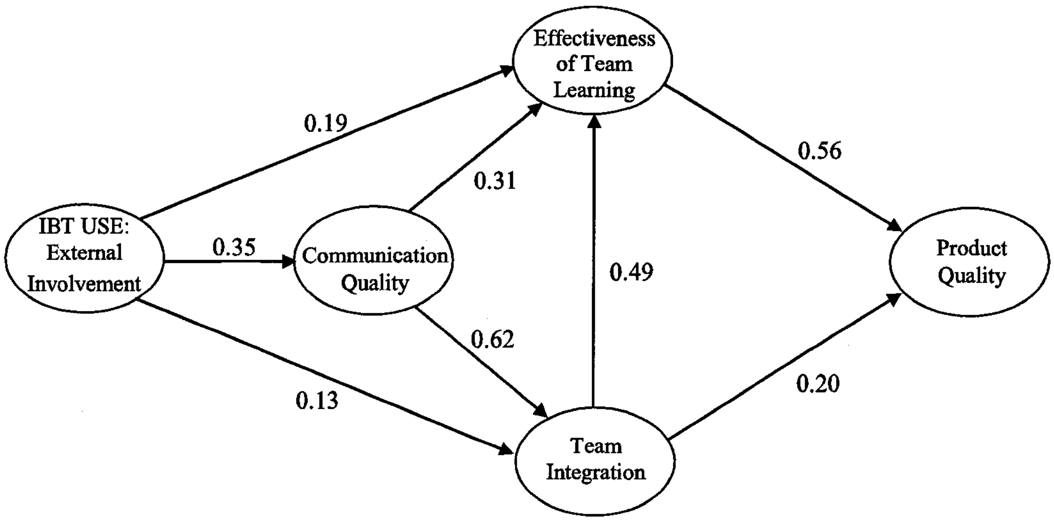


Figure 7.12 Model of the impact of IBT use for external partner involvement on product quality (Model C)

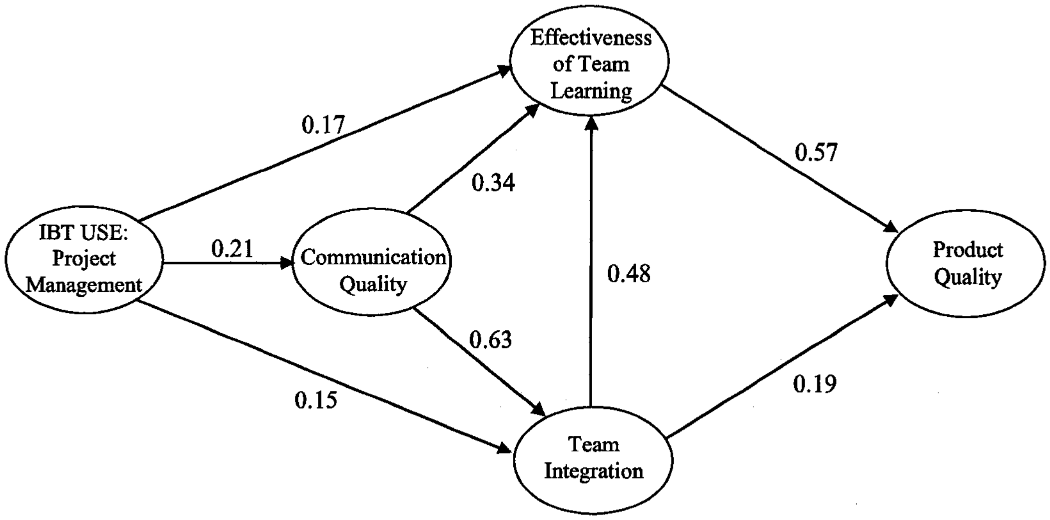


Figure 7.13 Model of the impact of IBT use for project management on product quality (Model D)

CHAPTER 8

IMPACT OF MODERATING VARIABLES

This chapter reports the results of a preliminary analysis of the effect of contextual variables on the relationships hypothesized in the proposed model. For selected moderating variables the following analysis was conducted: the responses were divided into two groups, characterized by either high score or low score on the given moderating variable; the proposed model was estimated using SEM methodology separately for each group; then a number of obtained results were compared: values of the path estimates, total and indirect effect of IBT use on the other variables, variance explained (R^2) and values of the model fit indices.

In order to make conclusions about the structural model differences between the groups, an assumption about measurement invariance across groups was first made. Measurement invariance may be defined with varying degrees of stringency, depending on which parameters are constrained to be equal. The following types of invariance were assumed to exist across the groups: invariance on number of factors; invariant factor loadings; equality of error variances and covariances across groups (however, it is important to note that according to some authors (e.g., Byrne, 2001) testing of equality constraints bearing on error variances and covariances is now considered to be excessively stringent). In order to interpret the standardized estimates, it is also assumed that indicators, measurement errors and disturbance terms have equal variances.

8.1 Product Innovativeness

Product innovativeness was hypothesized to influence the relationship between IBT use and NPD performance. The hypothesis was stated as follows:

Hypothesis 10 The impact of Internet-based technology use on NPD performance will be greater for highly innovative products compared to less innovative products.

In order to test this hypothesis, the sample was divided into two groups: one including development projects of innovative products (defined as either new-to-world products or product lines new to the firm) and the other including development projects of incremental products (defined as: incremental changes to existing products, major revisions to existing products, or additions to the firm's existing product lines). Given the fact, that all the respondents indicated the innovativeness level of the products under consideration, the resulting number of observations in the group of innovative products was 108 and in the group of incremental products was 170.

Next, six models were estimated: three models for incremental products (one model for each NPD performance dimension as a dependent variable) and three models for innovative products (one model for each NPD performance dimension as a dependent variable). The obtained unstandardized estimates are presented in Figure 8.1 to Figure 8.3. Estimation of the models indicated several insignificant paths. All these paths were kept in the models, given the following rationale: the values of the paths were usually greater than 0 and t-statistics were often close to the cut-off value of $t=1.96$. Therefore, the lack of significance of a given path may be related more to the small sample size, and not to the lack of significance of the path. All the path coefficients that were insignificant but were kept for the analysis are indicated in italics in Figure 8.1 to Figure 8.3.

The three models for innovative products have a good fit to data ($RMSEA_Q= 0.062$, $RMSEA_T= 0.062$, $RMSEA_C= 0.060$). They explain 24% of variance in communication quality, 81% of variance in effectiveness of team learning, 52% of variance in team integration, and, respectively, 67% of variance in product quality, 48% of variance in time-to-market, and 42% of variance in development cost. Out of this variance in dependent variables, the Internet-based technology use accounts for 24% of variance in communication quality, 55% of variance in effectiveness of team learning, 32% of variance in team integration, 35% of variance in product quality, 48% of variance in time-to-market, and 17% of variance in development cost.

Also the models for incremental products have a very good fit to data ($RMSEA_Q= 0.043$, $RMSEA_T= 0.044$, $RMSEA_C= 0.045$). However, they explain less variance in dependent variables than the models for innovative products: 4% of variance in communication quality, 57% of variance in effectiveness of team learning, 46% of variance in team integration and, respectively, 32% of variance in product quality, 23% of variance in time-to-market, and 19% of variance in development cost. Out of this variance in dependent variables, the Internet-based technology use accounts for 4% of variance in communication quality, 7.1% of variance in effectiveness of team learning, 8.7% of variance in team integration, 3% of variance in product quality, 9.2% of variance in time-to-market, and 2% of variance in development cost.

In order to test the hypothesis 10, i.e. to determine whether the impact of Internet-based technology use on NPD performance is greater for innovative products compared to incremental products, a series of z-tests was performed. The differences between direct and total effects obtained for innovative products and direct and total effects obtained for incremental products were calculated and their significance verified through a comparison to the one-tailed test statistic $z_{.05}$=1.645. All the calculated values are reported in Table 8.1.

When the effect of IBT use on teamwork processes (i.e. communication quality, effectiveness of team learning and team integration) are considered, the following observations can be made:

- Direct effect of IBT use on communication quality is significantly higher for innovative products than for incremental products.
- Direct effect of IBT use on team integration for innovative products does not significantly differ from the direct effect of IBT use on team integration for incremental products. However, the total effect of IBT use on team integration for innovative products is significantly higher for innovative products than for

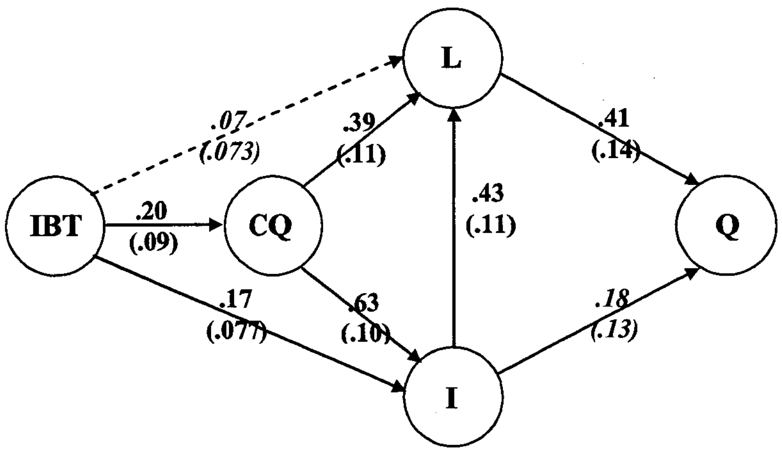
incremental products. It is related to the fact that in case of innovative products IBT use has greater impact on communication quality and therefore, indirectly, on team integration.

- Both direct effect and total effect of IBT use on effectiveness of team learning are significantly higher for innovative products than for incremental products.

When the NPD performance is analyzed, the following results of testing of the hypothesis 10 can be reported:

- There are no significant differences between the two groups (innovative products versus incremental products) as far as the effects of team integration and effectiveness of team learning on product quality, time-to-market, and development costs are considered.
- The total effect of IBT use on product quality is significantly higher for innovative products than for incremental products (β_1=.48, β_2=.16, z=3.20).
- The total effect of IBT use on time-to-market is significantly higher for innovative products than for incremental products (β_1=.55, β_2=.27, z=1.94), although there is no significant difference between the two groups when the direct effect of IBT use on time-to-market is considered.
- The total impact of IBT use on development cost is significantly higher for innovative products than for incremental products (β_1=.40, β_2=.14, z=2.33).

Product Quality: Model for Incremental Products

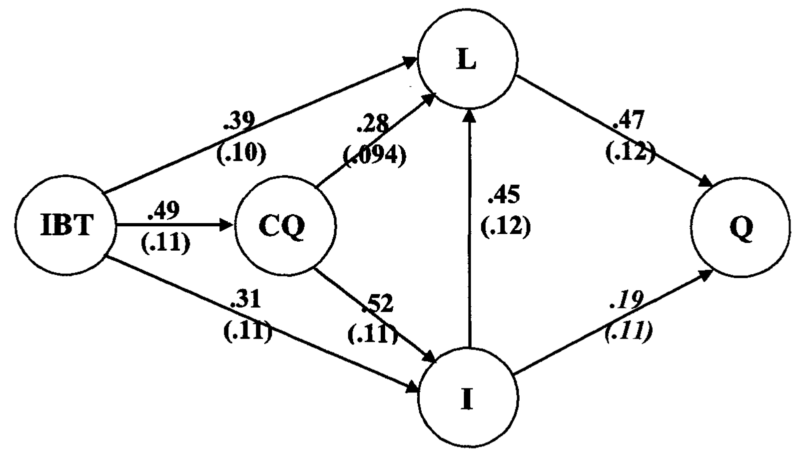


$\chi^2 = 1107.50$ df = 842 RMSEA$_Q$ = 0.043 n = 170

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.20(.09)	----	.20(.09)	4%	4%
IBT→L	.07(.07)	.20(.07)	.27(.09)	7.4%	58%
IBT→I	.17(.08)	.12(.06)	.29(.09)	8.7%	47%
IBT→Q	----	.16(.06)	.16(.06)	3%	32%

Product Quality: Model for Innovative Products



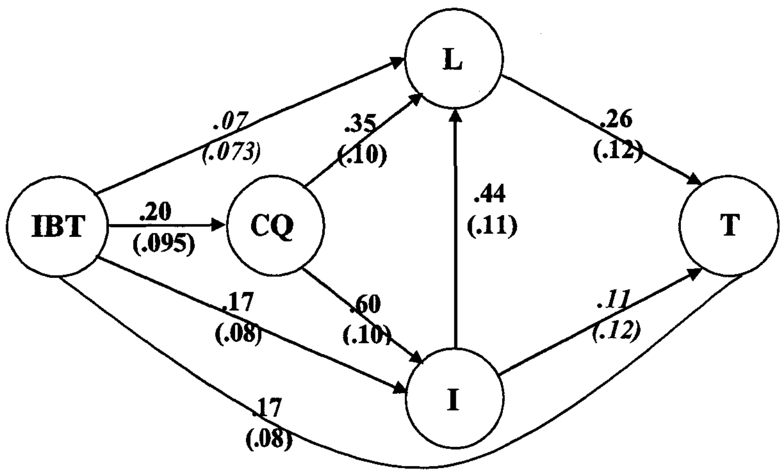
$\chi^2 = 1187.22$ df = 842 RMSEA$_Q$ = 0.062 n = 108

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.49(.11)	----	.49(.11)	24%	24%
IBT→L	.39(.10)	.39(.09)	.79(.14)	55%	81%
IBT→I	.31(.11)	.25(.07)	.57(.12)	32%	51%
IBT→Q	----	.48(.08)	.48(.08)	35%	67%

Figure 8.1 IBT use and product quality: moderating role of product innovativeness

Time-to-Market: Model for Incremental Products

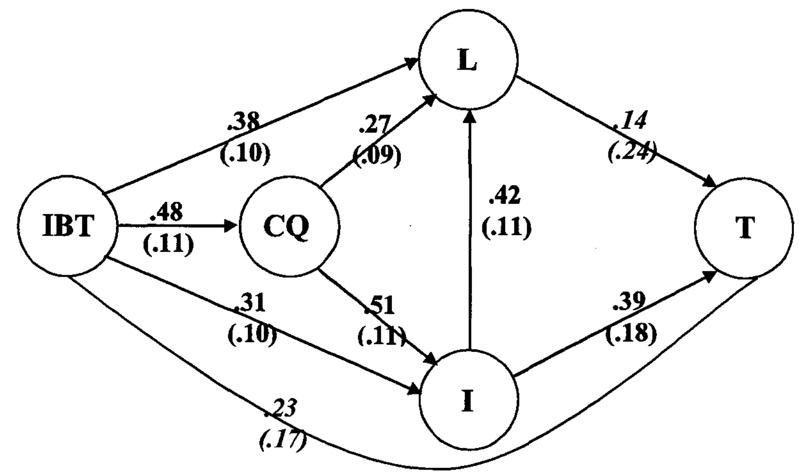


$\chi^2 = 1067.87$ df = 800 $RMSEA_T = 0.044$ n = 170

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.20(.09)	----	.20(.09)	4%	4%
IBT→L	.07(.07)	.20(.07)	.26(.09)	7.1%	57%
IBT→I	.17(.08)	.12(.06)	.29(.09)	8.7%	46%
IBT→T	.17(.08)	.10(.04)	.27(.08)	9.3%	23%

Time-to-Market: Model for Innovative Products



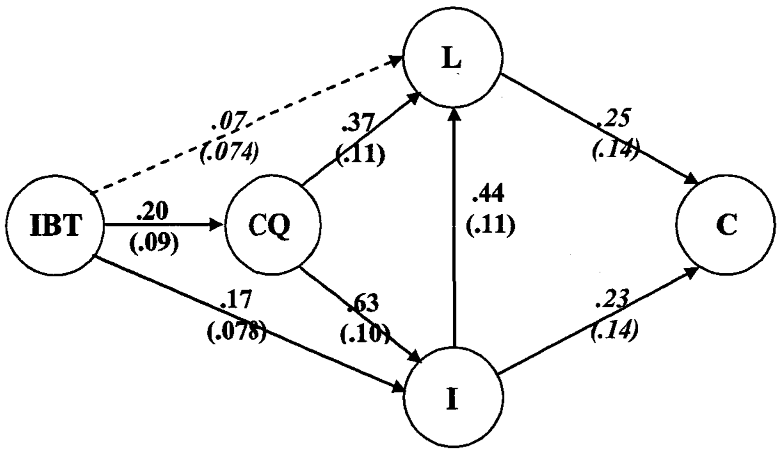
$\chi^2 = 1135.55$ df = 800 $RMSEA_T = 0.062$ n = 108

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.48(.11)	----	.48(.11)	24%	24%
IBT→L	.38(.10)	.37(.08)	.74(.14)	55%	81%
IBT→I	.31(.10)	.25(.07)	.56(.12)	31%	52%
IBT→T	.23(.17)	.32(.13)	.55(.12)	32%	48%

Figure 8.2 IBT use and time-to-market: moderating role of product innovativeness

Development Cost: Model for Incremental Products

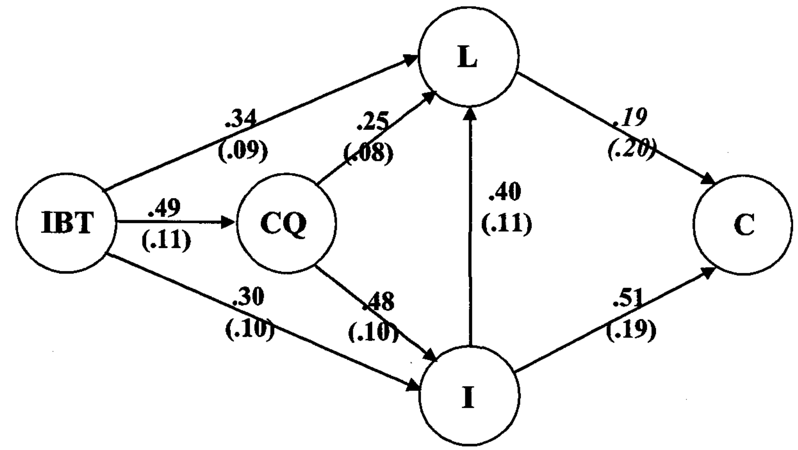


$\chi^2 = 1082.03$ df = 801 RMSEA$_C$ = 0.045 n = 170

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.20(.09)	----	.20(.09)	4%	4%
IBT→L	.07(.07)	.20(.07)	.27(.09)	7.5%	57%
IBT→I	.17(.08)	.12(.06)	.30(.09)	8.7%	46%
IBT→C	----	.14(.05)	.14(.05)	2%	19%

Development Cost: Model for Innovative Products



$\chi^2 = 1108.66$ df = 801 RMSEA$_C$ = 0.060 n = 108

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.49(.11)	----	.49(.11)	24%	24%
IBT→L	.34(.09)	.34(.08)	.68(.12)	55%	81%
IBT→I	.30(.10)	.24(.07)	.54(.11)	32%	52%
IBT→C	----	.40(.10)	.40(.10)	17%	42%

Figure 8.3 IBT use and development cost: moderating role of product innovativeness

Table 8.1 Hypothesis testing: innovative products versus incremental products

	Model of Product Quality					Model of Time-to-Market					Model of Development Cost					
	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	
IBT→CQ	.49	.11	.20	.09	**2.04**	.48	.11	.20	.09	**1.97**	.49	.11	.20	.09	**2.04**	S
CQ→Integration	.52	.11	.63	.10	**-0.74**	.51	.11	.60	.10	**-0.61**	.48	.10	.63	.10	**-1.06**	NS
CQ→Learning	.28	.09	.39	.11	**-0.77**	.27	.09	.35	.10	**-0.59**	.25	.08	.37	.11	**-0.88**	NS
IBT→Integration	.31	.11	.17	.08	**1.03**	.31	.10	.17	.08	**1.09**	.30	.10	.17	.08	**1.02**	NS
IBT→Integration(T)	.57	.12	.29	.09	**1.87**	.56	.12	.29	.09	**1.80**	.54	.11	.30	.09	**1.69**	S
IBT→Learning	.39	.10	.07	.07	**2.62**	.38	.10	.07	.07	**2.54**	.34	.09	.07	.07	**2.37**	S
IBT→Learning(T)	.79	.14	.27	.09	**3.12**	.74	.14	.26	.09	**2.88**	.68	.12	.27	.09	**2.73**	S
Integration→Learn	.45	.12	.43	.11	**0.12**	.42	.11	.44	.11	**-0.13**	.40	.11	.44	.11	**-0.26**	NS
Integration →Quality	.19	.11	.18	.13	**0.06**											NS
Learning→Quality	.47	.12	.41	.14	**0.33**											NS
IBT→Quality(T)	.48	.08	.16	.06	**3.20**											S
Integration →Time						.39	.18	.11	.12	**1.29**						NS
Learning→Time						.14	.24	.26	.12	**-0.45**						NS
IBT→Time						.23	.17	.17	.08	**0.32**						NS
IBT→Time(T)						.55	.12	.27	.08	**1.94**						S
Integration →Cost											.51	.19	.23	.14	**1.19**	NS
Learning→Cost											.19	.20	.25	.14	**-0.25**	NS
IBT→Cost(T)											.40	.10	.14	.05	**2.33**	S

- B1 and SE(B1) are values obtained for the models estimated for innovative products
- B2 and SE(B2) are values obtained for the models estimated for incremental products
- (T) indicates total effects
- S indicates a significant difference between two groups, NS indicates a non-significant difference between two groups

8.2 Technology Novelty

Another factor that was hypothesized to affect the relationship between Internet-based technology use during product development and NPD performance was technology novelty. Based on the literature review, the following hypothesis was forwarded:

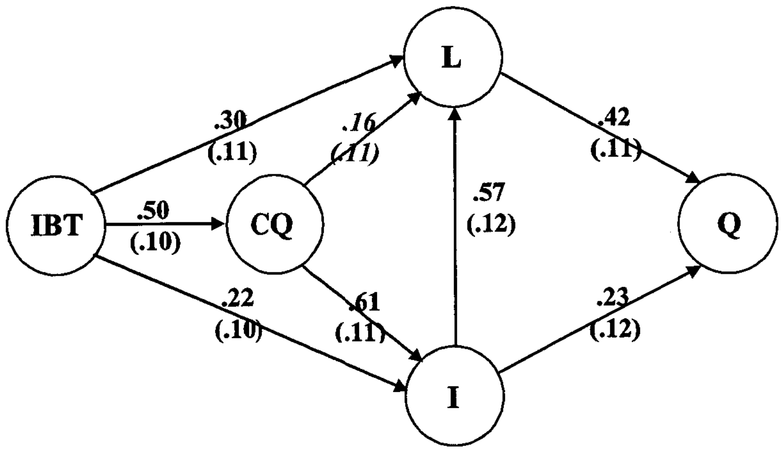
Hypothesis 12 The impact of Internet-based technology use on NPD performance will be greater for projects characterized by high technology novelty compared to projects characterized by low technology novelty.

In order to capture technology novelty, the respondents were asked to indicate their level of agreement (on a scale from 1 = strongly disagree to 5 = strongly agree) with the following technology novelty statement: "The technologies used in this product were new (unfamiliar) to the project team members". To be able to test Hypothesis 12, the collected responses were divided into two groups: one including projects in which the technology used in the product was unfamiliar to the project team members (scores 3, 4, 5 on the technology novelty question) and the other including projects in which the technology was familiar to the project team members (score 1 or 2 on the technology novelty question).

The resulting number of observations in the unfamiliar technology group was 153, while the resulting number of observations in the familiar technology group was 122 (three respondents did not respond to the technology novelty question). Next, similarly like in case of product innovativeness, six models were estimated: three models for unfamiliar technology (one model for each NPD performance dimension as a dependent variable) and three models for familiar technology (one model for each NPD performance dimension as a dependent variable). The obtained unstandardized estimates are presented in Figure 8.4 to Figure 8.6 (insignificant paths are indicated in italics).

All the models for unfamiliar technology products fit the data very well ($RMSEA_Q$ = 0.045, $RMSEA_T$ = 0.048, $RMSEA_C$ = 0.048). Similarly, the models for familiar technology products have good fit to the data as well ($RMSEA_Q$ = 0.051, $RMSEA_T$ = 0.0452 $RMSEA_C$ = 0.052). Testing of the differences between parameter estimates obtained after estimation of models for products with unfamiliar technology and models for products with familiar technology indicated lack of significant differences between the two groups in terms of the impact of IBT use on NPD performance. The only significant difference was between the path from communication quality to effectiveness of team learning. Testing of this difference indicated that the value of the path from communication quality to effectiveness of team learning is higher for familiar technology products than for unfamiliar technology products. The results of testing of the differences are presented in Table 8.2.

Product Quality: Model for Unfamiliar Technology

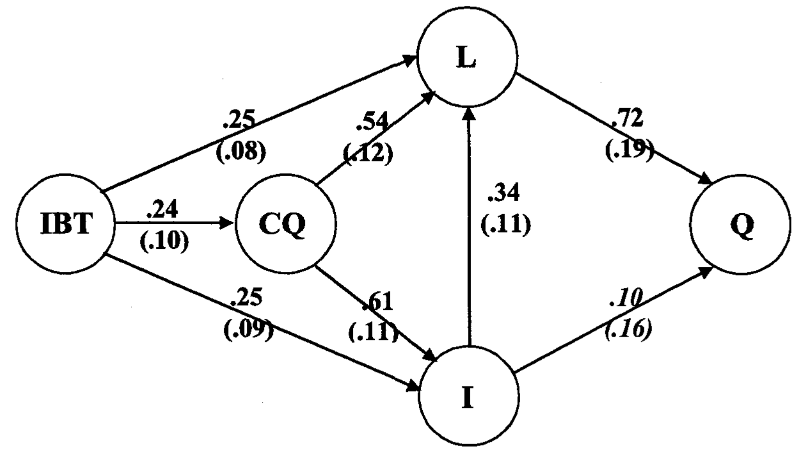


$\chi^2 = 1097.83$ df = 842 RMSEA = 0.045 n = 153

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.50(.10)	----	.50(.10)	24%	24%
IBT→L	.30(.11)	.38(.09)	.68(.12)	35%	65%
IBT→I	.22(.10)	.30(.08)	.52(.11)	24%	49%
IBT→Q	----	.40(.08)	.40(.08)	18%	51%

Product Quality: Model for Familiar Technology



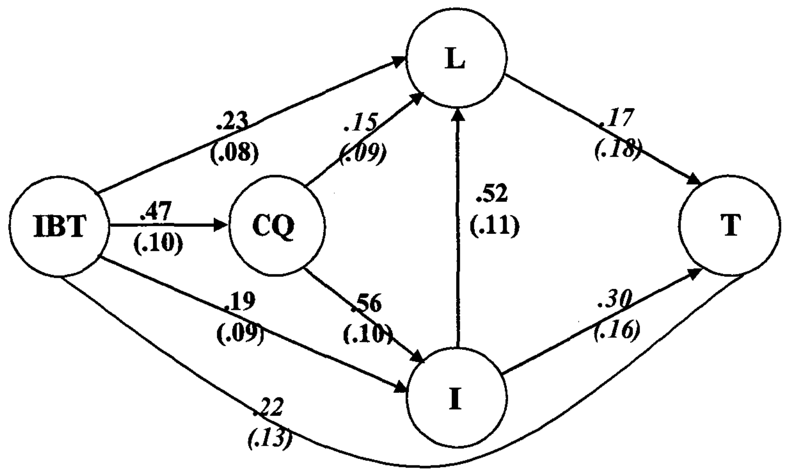
$\chi^2 = 1106.62$ df = 842 RMSEA = 0.051 n = 122

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.24(.10)	----	.24(.10)	6%	6%
IBT→L	.25(.08)	.26(.09)	.51(.12)	25%	76%
IBT→I	.25(.09)	.15(.06)	.40(.11)	16%	49%
IBT→Q	----	.41(.10)	.41(.10)	14%	55%

Figure 8.4 IBT use and product quality: moderating role of technology novelty

Time-to-Market: Model for Unfamiliar Technology

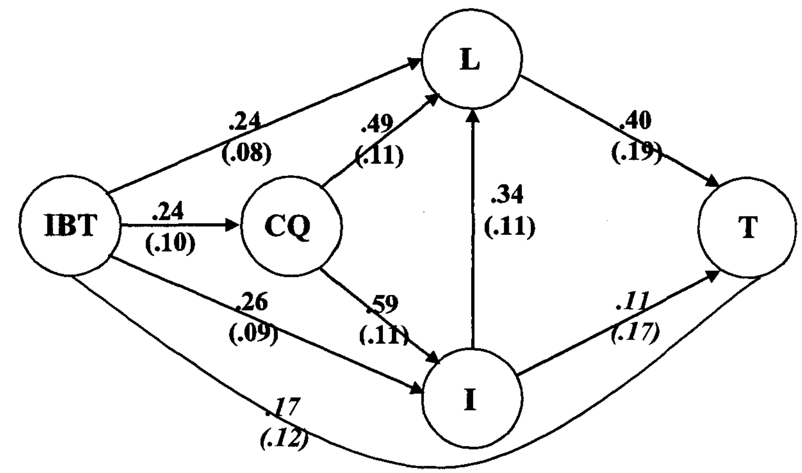


$\chi^2 = 1076.61$ df = 800 RMSEA = 0.048 n = 153

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.47(.10)	----	.47(.10)	21%	21%
IBT→L	.23(.08)	.31(.07)	.54(.10)	32%	64%
IBT→I	.19(.09)	.27(.07)	.45(.10)	21%	48%
IBT→T	.22(.13)	.23(.08)	.45(.11)	20%	34%

Time-to-Market: Model for Familiar Technology



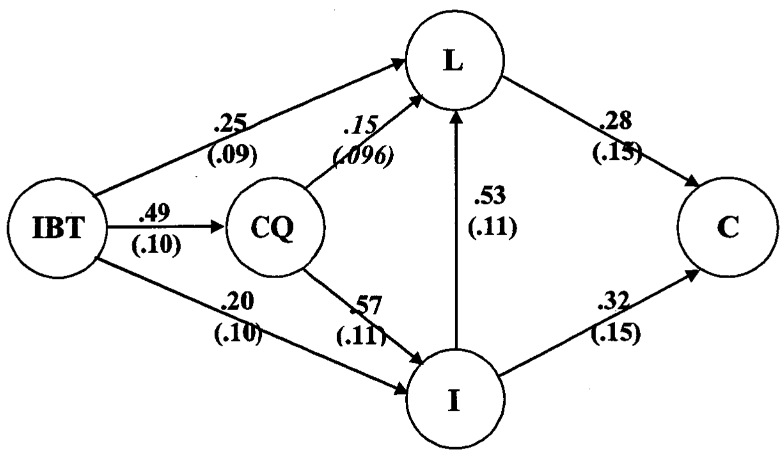
$\chi^2 = 1060.35$ df = 800 RMSEA = 0.052 n = 122

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.24(.10)	----	.24(.10)	5.7%	5.7%
IBT→L	.24(.08)	.25(.08)	.50(.12)	25%	75%
IBT→I	.25(.09)	.14(.06)	.40(.11)	16%	49%
IBT→T	.17(.12)	.24(.08)	.41(.12)	17%	34%

Figure 8.5 IBT use and time-to-market: moderating role of technology novelty

Development Cost: Model for Unfamiliar Technology

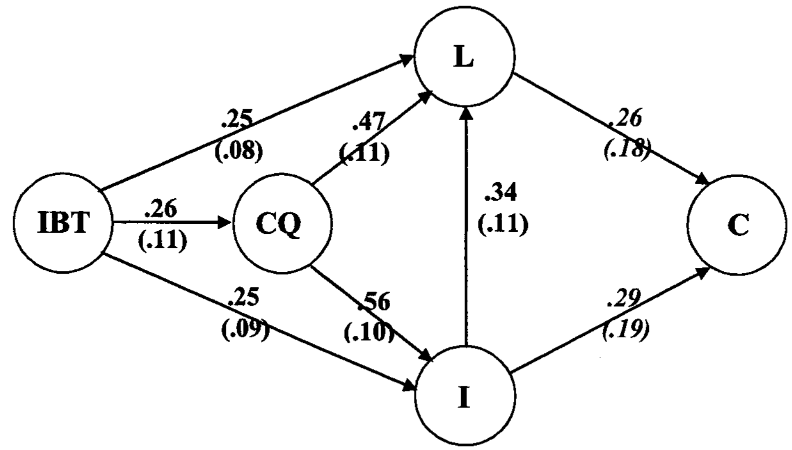


$\chi^2 = 1087.58$ df = 801 RMSEA = 0.048 n = 153

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.49(.10)	----	.49(.10)	24%	24%
IBT→L	.25(.09)	.33(.07)	.58(.11)	34%	64%
IBT→I	.20(.10)	.28(.07)	.48(.10)	23%	48%
IBT→C	----	.32(.07)	.32(.07)	10%	32%

Development Cost: Model for Familiar Technology



$\chi^2 = 1068.56$ df = 801 RMSEA = 0.052 n = 122

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.26(.11)	----	.26(.11)	6%	6%
IBT→L	.25(.08)	.26(.09)	.51(.12)	25%	76%
IBT→I	.25(.09)	.14(.06)	.40(.11)	16%	49%
IBT→C	----	.25(.08)	.25(.08)	5.5%	24%

Figure 8.6 IBT use and development cost: moderating role of technology novelty

Table 8.2 Hypothesis testing: unfamiliar technology versus familiar technology

	Model of Product Quality					Model of Time-to-Market					Model of Development Cost					
	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	
IBT→CQ	.50	.10	.24	.10	**1.84**	.47	.10	.24	.10	**1.63**	.49	.10	.26	.11	**1.55**	NS
CQ→Integration	.61	.11	.61	.11	**0.00**	.56	.10	.59	.11	**-0.20**	.57	.11	.56	.10	**0.07**	NS
CQ→Learning	.16	.11	.54	.12	**-2.33**	.15	.09	.49	.11	**-2.39**	.15	.10	.47	.11	**-2.15**	S
IBT→Integration	.22	.10	.25	.09	**-0.22**	.19	.09	.26	.09	**-0.55**	.20	.10	.25	.09	**-0.37**	NS
IBT→Integration(T)	.52	.11	.40	.11	**0.77**	.45	.10	.40	.11	**0.34**	.48	.10	.40	.11	**0.54**	NS
IBT→Learning	.30	.11	.25	.08	**0.37**	.23	.08	.24	.08	**-0.09**	.25	.09	.25	.08	**0.00**	NS
IBT→Learning(T)	.68	.12	.51	.12	**1.00**	.54	.10	.50	.12	**0.26**	.58	.11	.51	.12	**0.43**	NS
Integration→Learn	.57	.12	.34	.11	**1.41**	.52	.11	.34	.11	**1.16**	.53	.11	.34	.11	**1.22**	NS
Integration →Quality	.23	.12	.10	.16	**0.65**											NS
Learning→Quality	.42	.11	.72	.19	**-1.37**											NS
IBT→Quality(T)	.40	.08	.41	.10	**-0.08**											NS
Integration →Time						.30	.16	.11	.17	**0.81**						NS
Learning→Time						.17	.18	.40	.19	**-0.88**						NS
IBT→Time						.22	.13	.17	.12	**0.28**						NS
IBT→Time(T)						.45	.11	.41	.12	**0.25**						NS
Integration →Cost											.32	.15	.29	.19	**0.12**	NS
Learning→Cost											.28	.15	.26	.18	**0.09**	NS
IBT→Cost(T)											.32	.07	.25	.08	**0.66**	NS

- B1 and SE(B1) are values obtained for the models estimated for products involving technology unfamiliar to team members
- B2 and SE(B2) are values obtained for the models estimated for products involving technology familiar to team members
- (T) indicates total effects
- S indicates a significant difference between two groups, NS indicates a non-significant difference between two groups

8.3 Functional Diversity in Team

Next variable hypothesized to influence the relationship between IBT use and NPD performance was functional diversity in team. The following hypothesis was proposed:

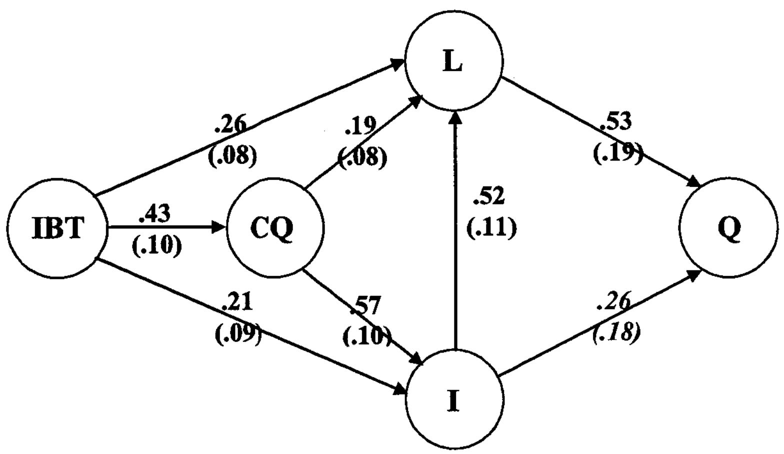
Hypothesis 13 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by teams with high functional diversity compared to projects conducted by teams with low functional diversity.

The sample was divided into two groups: projects executed by teams with high functional diversity and projects executed by teams with low functional diversity. The criterion used was the total number of functional areas and types of external organizations that were represented on the project team. The respondents were asked to indicate whether the following categories were represented on their teams: marketing and sales, research and development, purchasing, engineering/design, manufacturing, customer support, suppliers, customers, and partner firms. For each respondent the number of categories represented on the project team was calculated. Next, for respondents who indicated other functional areas or external organizations represented on their teams (such as quality department, consultants, or university), the number of these categories was also added to the count. Finally, the group of teams with high functional diversity included projects that were executed by teams that had representatives from at least 6 functional areas/ types of external organizations. The number of such teams was 150. The remaining projects, executed by teams with representatives from less than 6 functional areas/ types of external organizations, represented the second group, i.e. group of projects executed by 'teams with low functional diversity'. This group consisted of 128 projects.

In order to test the differences between the two groups, six models were estimated: three models for projects executed by teams with high functional diversity (one model for each NPD performance dimension as a dependent variable) and three models for projects executed by teams with low functional diversity (one model for each NPD performance dimension as a dependent variable). The obtained unstandardized estimates are presented in Figure 8.7 to Figure 8.9 (insignificant paths are indicated in italics).

All the estimated models for teams with high functional diversity fit the data very well ($RMSEA_Q$ = 0.052, $RMSEA_T$ = 0.052, $RMSEA_C$ = 0.055). Similarly, the models for teams with low diversity have good fit to the data as well ($RMSEA_Q$ = 0.051, $RMSEA_T$ = 0.051 $RMSEA_C$ = 0.051). When the obtained results are compared, it can be argued that IBT use explains more variance in communication quality, effectiveness of team learning and team integration in case of projects executed by highly diverse teams, as opposed to projects executed by less diverse teams. Also, for projects executed by diverse teams IBT use explains more variance in all the three NPD performance constructs than for projects executed by less diverse teams. These observations are consistent with the proposed hypothesis. However, when the actual testing of direct effects and total effects was conducted, all the differences were concluded to be statistically insignificant (see Table 8.3). It is important to note though, that the lack of statistical significance may be related to small sizes of the sub-samples and high errors and not to the actual lack of differences between the effects. Therefore, it will be possible to make final conclusions regarding the role of functional diversity in team only after a more detailed analysis is conducted.

Product Quality: Model for High Diversity Teams

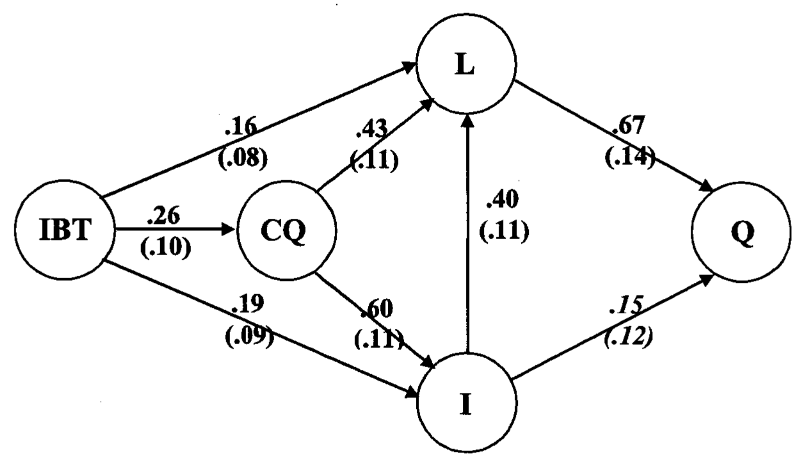


$\chi^2 = 1180.83$ df = 842 $RMSEA_Q = 0.052$ n = 150

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.43(.10)	----	.42(.10)	18%	18%
IBT→L	.26(.08)	.32(.07)	.58(.11)	36%	71%
IBT→I	.21(.09)	.24(.07)	.45(.10)	21%	49%
IBT→Q	----	.42(.10)	.42(.10)	15%	44%

Product Quality: Model for Low Diversity Teams



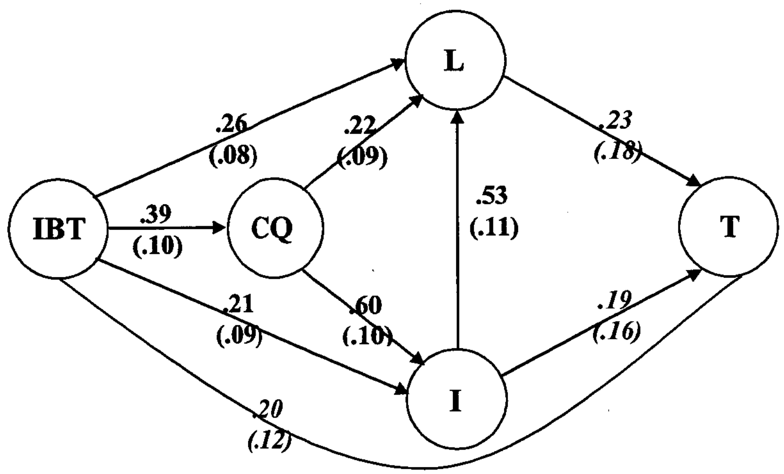
$\chi^2 = 1125.05$ df = 842 $RMSEA_Q = 0.051$ n = 128

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.26(.10)	----	.26(.10)	6.6%	6.6%
IBT→L	.16(.08)	.25(.08)	.41(.11)	17%	68%
IBT→I	.19(.09)	.15(.06)	.34(.11)	12%	45%
IBT→Q	----	.33(.09)	.33(.09)	11%	64%

Figure 8.7 IBT use and product quality: moderating role of team functional diversity

Time-to-Market: Model for High Diversity Teams

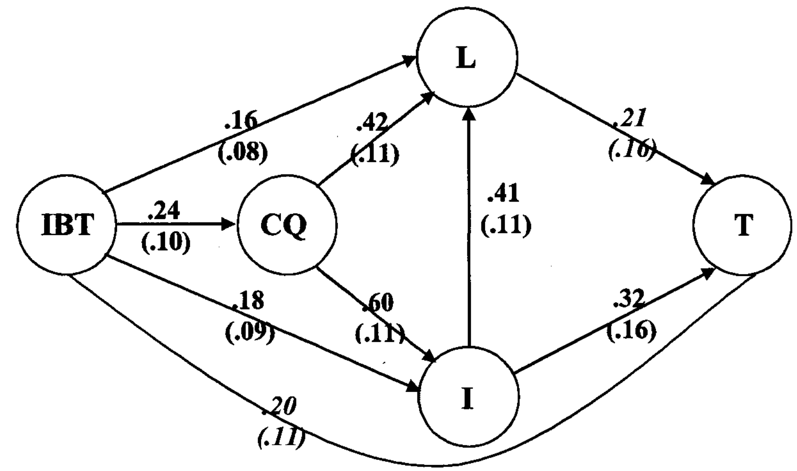


$\chi^2 = 1126.37$ df = 800 RMSEA$_T$ = 0.052 n = 150

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.39(.10)	----	.39(.10)	15%	15%
IBT→L	.26(.08)	.32(.08)	.58(.11)	33%	71%
IBT→I	.21(.09)	.23(.07)	.45(.10)	20%	49%
IBT→T	.20(.12)	.22(.07)	.42(.10)	19%	32%

Time-to-Market: Model for Low Diversity Teams



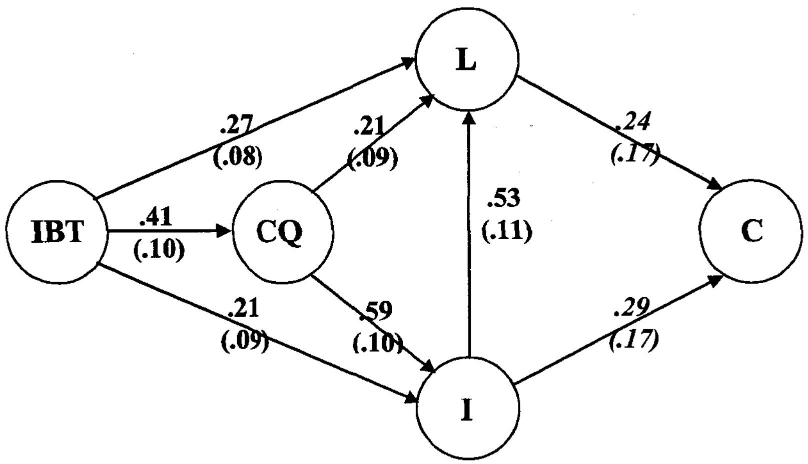
$\chi^2 = 1066.78$ df = 800 RMSEA$_T$ = 0.051 n = 128

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.24(.10)	----	.24(.10)	5.6%	5.6%
IBT→L	.16(.08)	.23(.08)	.39(.11)	15%	67%
IBT→I	.18(.09)	.14(.06)	.33(.11)	11%	45%
IBT→T	.20(.11)	.19(.07)	.39(.12)	15%	36%

Figure 8.8 IBT use and time-to-market: moderating role of team functional diversity

Development Cost: Model for High Diversity Teams

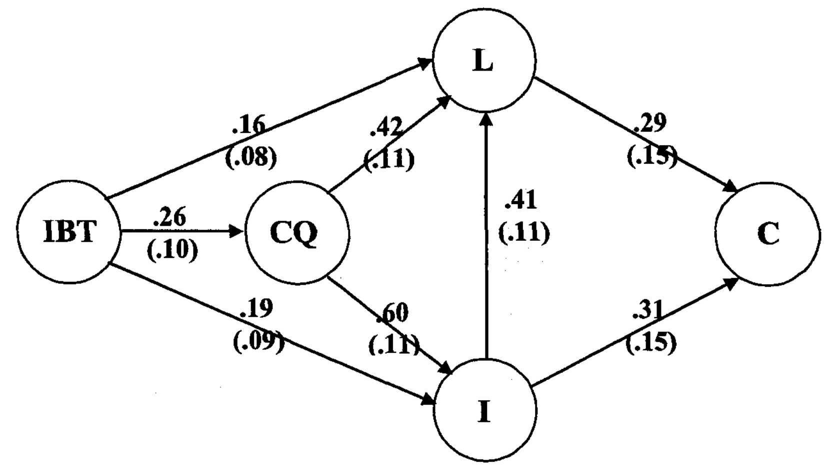


$\chi^2 = 1161.83$ df = 801 RMSEA$_C$ = 0.055 n = 150

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.41(.10)	----	.41(.10)	17%	17%
IBT→L	.27(.08)	.33(.07)	.59(.11)	35%	71%
IBT→I	.21(.09)	.24(.07)	.46(.10)	21%	49%
IBT→C	----	.28(.07)	.28(.07)	8.3%	28%

Development Cost: Model for Low Diversity Teams



$\chi^2 = 1072.35$ df = 801 RMSEA$_C$ = 0.051 n = 128

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.26(.10)	----	.26(.10)	6.6%	6.6%
IBT→L	.16(.08)	.25(.08)	.41(.11)	17%	67%
IBT→I	.19(.09)	.15(.06)	.34(.11)	12%	45%
IBT→C	----	.23(.07)	.23(.07)	5.5%	34%

Figure 8.9 IBT use and development cost: moderating role of team functional diversity

Table 8.3 Hypothesis testing: high diversity teams versus low diversity teams

	Model of Product Quality					Model of Time-to-Market					Model of Development Cost					
	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	
IBT→CQ	.43	.10	.26	.10	**1.20**	.39	.10	.24	.10	**1.06**	.41	.10	.26	.10	**1.06**	NS
CQ→Integration	.57	.10	.60	.11	**-0.20**	.60	.10	.60	.11	**0.00**	.59	.10	.60	.11	**-0.07**	NS
CQ→Learning	.19	.08	.43	.11	**-1.76**	.22	.09	.42	.11	**-1.41**	.21	.09	.42	.11	**-1.48**	NS
IBT→Integration	.21	.09	.19	.09	**0.16**	.21	.09	.18	.09	**0.24**	.21	.09	.19	.09	**0.16**	NS
IBT→Integration(T)	.45	.10	.34	.11	**0.74**	.45	.10	.33	.11	**0.81**	.46	.10	.34	.11	**0.81**	NS
IBT→Learning	.26	.08	.16	.08	**0.88**	.26	.08	.16	.08	**0.88**	.27	.08	.16	.08	**0.97**	NS
IBT→Learning(T)	.58	.11	.41	.11	**1.09**	.58	.11	.39	.11	**1.22**	.59	.11	.41	.11	**1.16**	NS
Integration→Learn	.52	.11	.40	.11	**0.77**	.53	.11	.41	.11		.53	.11	.41	.11	**0.77**	NS
Integration →Quality	.26	.18	.15	.12	**0.51**											NS
Learning→Quality	.53	.19	.67	.14	**-0.59**											NS
IBT→Quality(T)	.42	.10	.33	.09	**0.67**											NS
Integration →Time						.19	.16	.32	.16	**-0.57**						NS
Learning→Time						.23	.18	.21	.16	**0.08**						NS
IBT→Time						.20	.12	.20	.11	**0.00**						NS
IBT→Time(T)						.42	.10	.39	.12	**0.19**						NS
Integration →Cost											.29	.17	.31	.15	**-0.09**	NS
Learning→Cost											.24	.17	.29	.15	**-0.22**	NS
IBT→Cost(T)											.28	.07	.23	.07	**0.51**	NS

- B1 and SE(B1) are values obtained for the models estimated for projects executed by teams with high functional diversity
- B2 and SE(B2) are values obtained for the models estimated for projects executed by teams with low functional diversity
- (T) indicates total effects
- S indicates a significant difference between two groups, NS indicates a non-significant difference between two groups

8.4 Team Proximity

Team proximity was the next contextual factor hypothesized to affect the relationships among the variables in the proposed model. The proposed hypothesis stated:

Hypothesis 14 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by highly dispersed (global) teams compared to projects conducted by collocated (local) teams.

The variable of team proximity was captured by asking the respondents to indicate where the NPD project team members were located: in one building/office; in several locations but one city; in several cities but one country; and in more than one country. In order to conduct a comparison between two groups characterized by high and low team proximity, the following two categories were introduced: local teams and global teams. Local teams include teams that were either located in one building/office or in several locations within one city (119 cases). The global teams, on the other hand, encompass projects that were executed by teams located in several cities (locations) within one or more countries (159 cases).

Next, six models were estimated: three models for local teams (one model for each NPD performance dimension as a dependent variable) and three models for global teams (one model for each NPD performance dimension as a dependent variable). The obtained unstandardized estimates are presented in Figure 8.10 – Figure 8.12. Estimation of the models indicated several insignificant paths. However, like in the case of other moderating variables, these paths are kept in the model and cautiously interpreted. All the models for local teams fit the data very well ($RMSEA_Q$= 0.061, $RMSEA_T$=0.060, $RMSEA_C$=0.059). Similarly, the models for global teams have good fit to the data as well ($RMSEA_Q$= 0.047, $RMSEA_T$= 0.048 $RMSEA_C$= 0.050).

When the direct and total effects of IBT use on communication quality, effectiveness of team learning and team integration are compared across the two groups, several observations can be made:

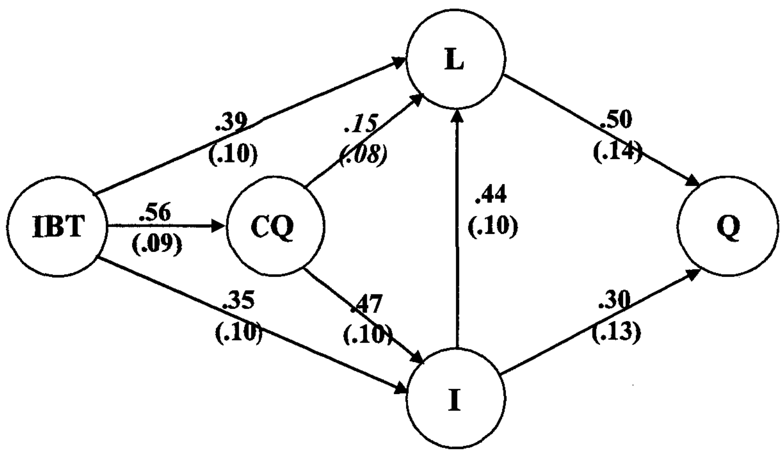
- Direct and at the same time total effect of IBT use on communication quality is significantly higher in case of global teams than in local teams (β_1=0.56, β_2=0.19, z=2.60). As a result, IBT use accounts for 30% of variance in communication quality in projects executed by global teams compared to 3.2% of variance in communication quality in projects executed by local teams.
- The total impact of IBT use on team integration is significantly higher for projects executed by global teams than for projects executed by local teams (β_1=0.62, β_2=0.24, z=2.56). IBT use accounts for 38% of variability in team integration when projects are executed by global teams, compared to 5.7% in case of projects executed by local teams.
- The direct effect of IBT use on effectiveness of team learning is significantly higher for projects executed by global teams then for projects executed by local teams (β_1=0.39, β_2=0.07, z=2.62). Also, the total effect of IBT use on effectiveness of team learning is significantly higher for projects executed by global teams then for

projects executed by local teams (β_1=0.75, β_2=0.26, z=3.01). In case of global teams IBT use accounts for 56% of variability in effectiveness of team learning, while in case of local teams – only for 7.2%.

When different dimensions of NPD performance are considered, the following observations about the total impact of IBT use on NPD performance can be made:

- The total impact of IBT use on product quality is significantly higher (z=3.16) in case of projects executed by global teams (β_1=0.56; 31% of variance explained) than in case of projects executed by local teams (β_2=0.18; 3% of variance explained).
- There is lack of significant difference between the direct effect of IBT use on time-to-market in the group of projects executed by global teams and the direct effect of IBT use on time-to-market in the group of projects executed by local teams.
- There is no significant difference between the total effect of IBT use on time-to-market in projects executed by global teams and the total effect of IBT use on time-to-market in projects executed by local teams.
- The total impact of IBT use on development cost is significantly higher (z=2.40) in case of projects executed by global teams (β_1=0.38; 15% of variance explained) than in case of projects executed by local teams (β_1=0.14; 2% of variance explained).

Product Quality: Model for Global Teams

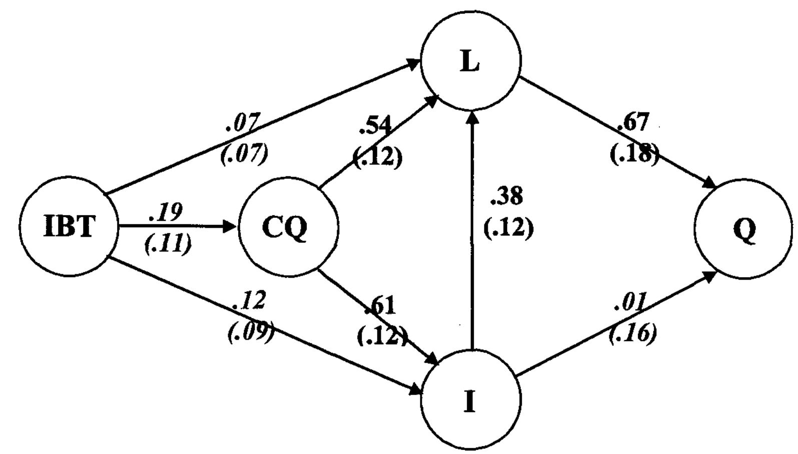


χ^2 = 1143.31 df = 842 RMSEA = 0.047 n = 159

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.56(.09)	----	.56(.09)	32%	32%
IBT→L	.39(.10)	.36(.07)	.75(.12)	56%	74%
IBT→I	.35(.10)	.26(.06)	.62(.10)	38%	53%
IBT→Q	----	.56(.09)	.56(.09)	31%	57%

Product Quality: Model for Local Teams



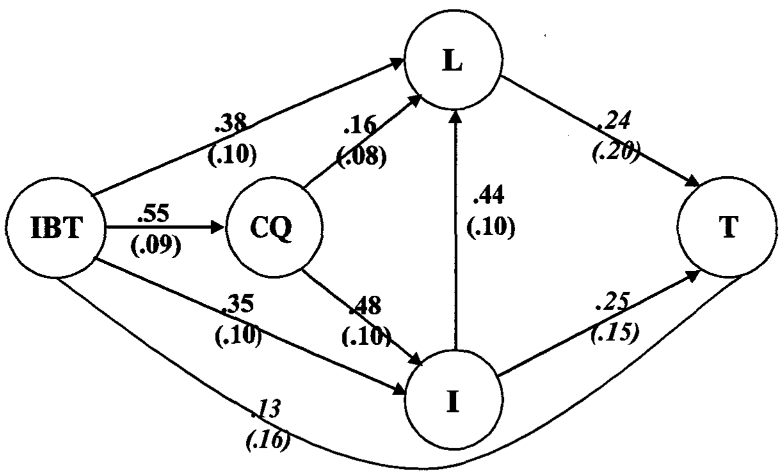
χ^2 = 1216.45 df = 842 RMSEA = 0.061 n = 159

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.19(.11)	----	.19(.11)	3.8%	3.8%
IBT→L	.07(.07)	.19(.09)	.26(.11)	6.9%	72%
IBT→I	.12(.09)	.12(.07)	.24(.11)	5.6%	41%
IBT→Q	----	.18(.08)	.18(.08)	3%	43%

Figure 8.10 IBT use and product quality: moderating role of team proximity

Time-to-Market: Model for Global Teams

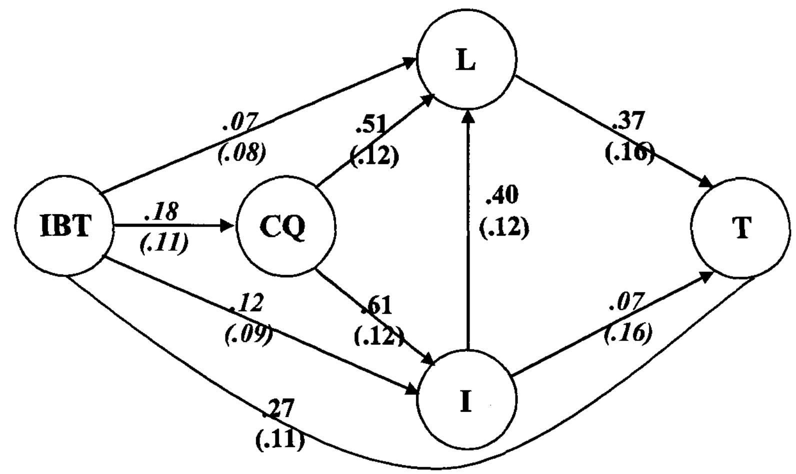


$\chi^2 = 1095.76$ df = 800 RMSEA = 0.048 n = 159

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.55(.09)	----	.55(.09)	30%	30%
IBT→L	.38(.10)	.36(.07)	.74(.12)	55%	74%
IBT→I	.35(.10)	.26(.6)	.61(.10)	38%	53%
IBT→T	.13(.16)	.33(12)	.47(.11)	22%	33%

Time-to-Market: Model for Local Teams



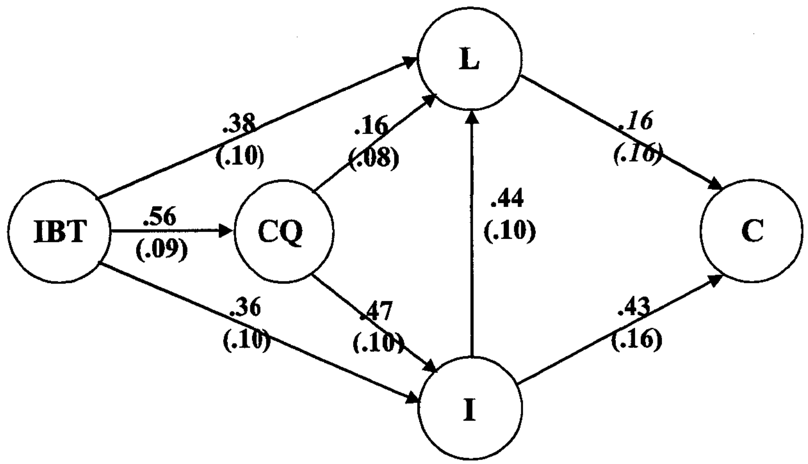
$\chi^2 = 1142.76$ df = 800 RMSEA = 0.060 n = 119

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.18(.11)	----	.18(.11)	3.2%	3.2%
IBT→L	.07(.08)	.18(.09)	.25(.11)	6.3%	69%
IBT→I	.12(.09)	.11(.07)	.23(.11)	5.3%	41%
IBT→T	.27(.11)	.11(.05)	.38(.11)	15%	32%

Figure 8.11 IBT use and time-to-market: moderating role of team proximity

Development Cost: Model for Global Teams

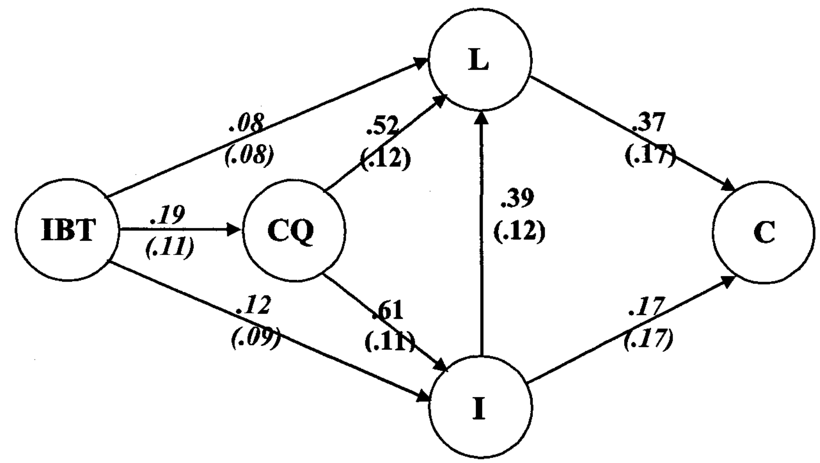


$\chi^2 = 1113.30$ df = 801 RMSEA = 0.050 n = 159

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.56(.09)	----	.56(.09)	31%	31%
IBT→L	.38(.10)	.36(.07)	.75(.12)	56%	74%
IBT→I	.36(.10)	.26(.06)	.62(.10)	38%	53%
IBT→C	----	.38(.08)	.38(.08)	15%	32%

Development Cost: Model for Local Teams



$\chi^2 = 1133.86$ df = 801 RMSEA = 0.059 n = 159

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.19(.11)	----	.19(.11)	3.7%	3.7%
IBT→L	.08(.08)	.19(.09)	.27(.11)	7.2%	70%
IBT→I	.12(.09)	.12(.07)	.24(.11)	5.7%	41%
IBT→C	----	.14(.06)	.14(.06)	2%	26%

Figure 8.12 IBT use and development cost: moderating role of team proximity

Table 8.4 Hypothesis testing: global teams versus local teams

	Model of Product Quality					Model of Time-to-Market					Model of Development Cost					
	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	
IBT→CQ	.56	.09	.19	.11	**2.60**	.55	.09	.18	.11	**2.60**	.56	.09	.19	.11	**2.60**	S
CQ→Integration	.47	.10	.61	.12	**-0.90**	.48	.10	.61	.12	**-0.83**	.47	.10	.61	.11	**-0.94**	NS
CQ→Learning	.15	.08	.54	.12	**-2.70**	.16	.08	.51	.12	**-2.43**	.16	.08	.52	.12	**-2.50**	S
IBT→Integration	.35	.10	.12	.09	**1.71**	.35	.10	.12	.09	**1.71**	.36	.10	.12	.09	**1.78**	S
IBT→Integration(T)	.62	.10	.24	.11	**2.56**	.61	.10	.23	.11	**2.56**	.62	.10	.24	.11	**2.56**	S
IBT→Learning	.39	.10	.07	.07	**2.62**	.38	.10	.07	.08	**2.42**	.38	.10	.08	.08	**2.34**	S
IBT→Learning(T)	.75	.12	.26	.11	**3.01**	.74	.12	.25	.11	**3.01**	.75	.12	.27	.11	**2.95**	S
Integration→Learn	.44	.10	.38	.12	**0.38**	.44	.10	.40	.12	**0.26**	.44	.10	.39	.12	**0.32**	NS
Integration →Quality	.30	.13	.01	.16	**1.41**											NS
Learning→Quality	.50	.14	.67	.18	**-0.75**											NS
IBT→Quality(T)	.56	.09	.18	.08	**3.16**											S
Integration →Time						.25	.15	.07	.16	**0.82**						NS
Learning→Time						.24	.20	.37	.16	**-0.51**						NS
IBT→Time						.13	.16	.27	.11	**-0.72**						NS
IBT→Time(T)						.47	.11	.38	.11	**0.58**						NS
Integration →Cost											.43	.16	.17	.17	**1.11**	NS
Learning→Cost											.16	.16	.37	.17	**-0.90**	NS
IBT→Cost(T)											.38	.08	.14	.06	**2.40**	S

- B1 and SE(B1) are values obtained for the models estimated for projects executed by global teams
- B2 and SE(B2) are values obtained for the models estimated for projects executed by local teams
- (T) indicates total effects
- S indicates a significant difference between two groups, NS indicates a non-significant difference between two groups

8.5 Team Size

Next variable hypothesized to influence the relationship between IBT use and NPD performance was team size. The hypothesis was formulated as follows:

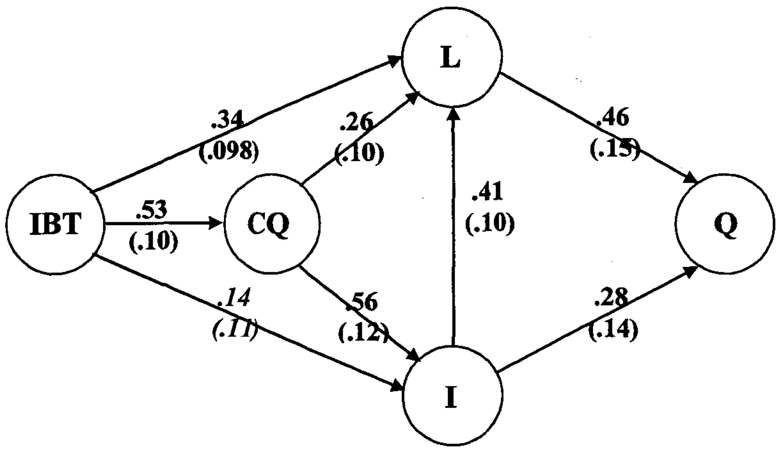
Hypothesis 15 The impact of Internet-based technology on NPD performance will be greater for projects conducted by large teams compared to projects conducted by small teams.

Again, the sample was divided into two groups: projects executed by small teams and projects executed by large teams. The criterion used was the total number of team members (sum of internal team members and external team members). The group of 'small team' projects consists of projects executed by teams of 10 or less members (N = 145) The group of 'large team' projects consists of projects executed by teams of more than 10 members (N = 132).

Three models were estimated for each of the groups: one for each dimension of performance. The resulting path estimates are presented in Figure 8.13 – Figure 8.15. In order to investigate if any significant differences between estimated path coefficients were present, a series of z-tests were conducted, see Table 8.5. The performed analysis indicated that:

- The effect of IBT use on communication quality is significantly higher in case of projects executed by large teams than in case of projects executed by small teams.

Product Quality: Model for Large Teams

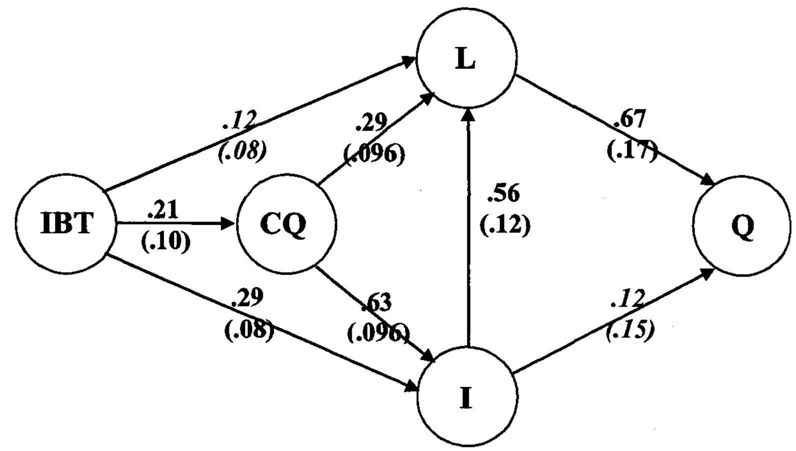


χ^2 = 1158.56 df = 842 RMSEA$_Q$ = 0.053 n = 132

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.53(.10)	----	.53(.10)	29%	29%
IBT→L	.34(.10)	.32(.08)	.66(.12)	43%	71%
IBT→I	.14(.11)	.30(.08)	.44(.11)	19%	42%
IBT→Q	----	.42(.09)	.42(.09)	18%	47%

Product Quality: Model for Small Teams



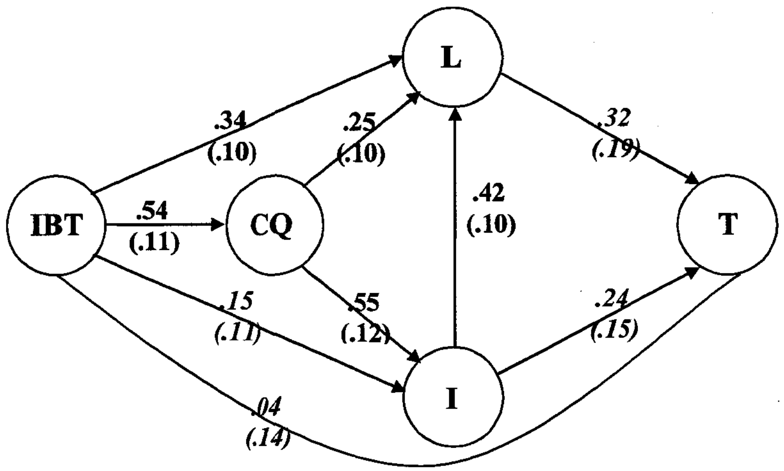
χ^2 = 1150.08 df = 842 RMSEA$_Q$ = 0.050 n = 145

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.21(.10)	----	.21(.10)	4.3%	4.3%
IBT→L	.12(.08)	.29(.09)	.41(.11)	17%	70%
IBT→I	.29(.08)	.13(.06)	.42(.10)	17%	55%
IBT→Q	----	.32(.08)	.32(.08)	10%	58%

Figure 8.13 IBT use and product quality: moderating role of team size

Time-to-Market: Model for Large Teams

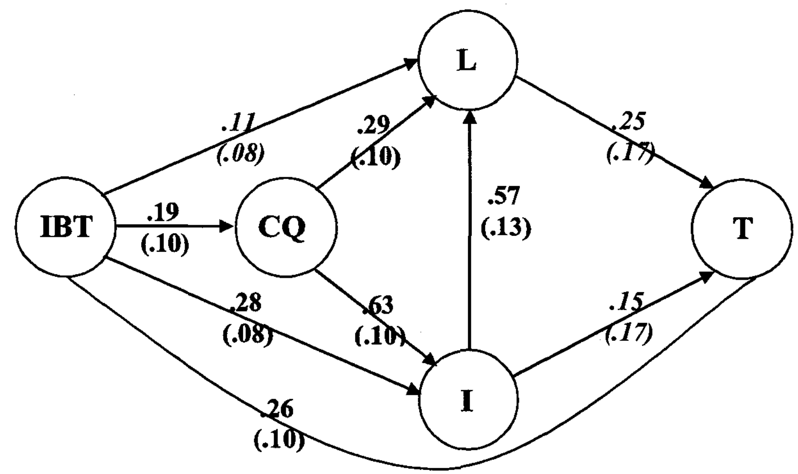


$\chi^2 = 1049.92$ df = 800 $RMSEA_T = 0.049$ n = 132

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.54(.11)	----	.54(.11)	28%	28%
IBT→L	.34(.10)	.32(.08)	.66(.12)	43%	70%
IBT→I	.15(.11)	.30(.08)	.45(.11)	19%	41%
IBT→T	.04(.14)	.32(.10)	.36(.11)	14%	34%

Time-to-Market: Model for Small Teams



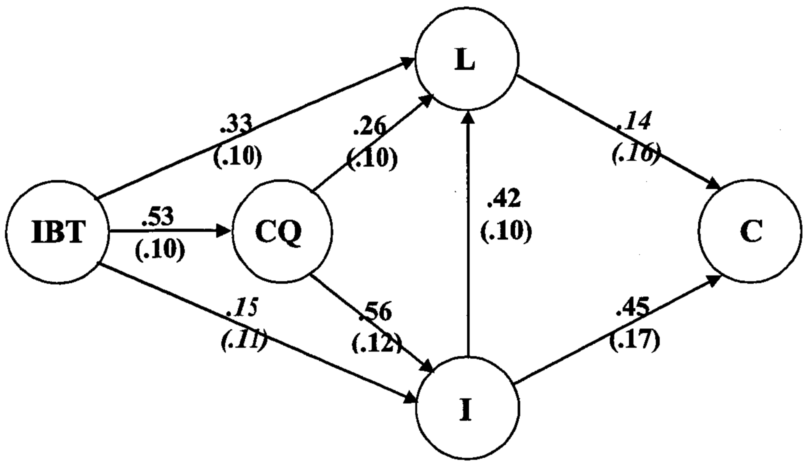
$\chi^2 = 1126.35$ df = 800 $RMSEA_T = 0.053$ n = 145

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.19(.10)	----	.19(.10)	3.6%	3.6%
IBT→L	.11(.08)	.29(.09)	.39(.11)	15%	69%
IBT→I	.28(.08)	.12(.06)	.40(.10)	16%	55%
IBT→T	.26(.10)	.16(.05)	.42(.10)	20%	34%

Figure 8.14 IBT use and time-to-market: moderating role of team size

Development Cost: Model for Large Teams

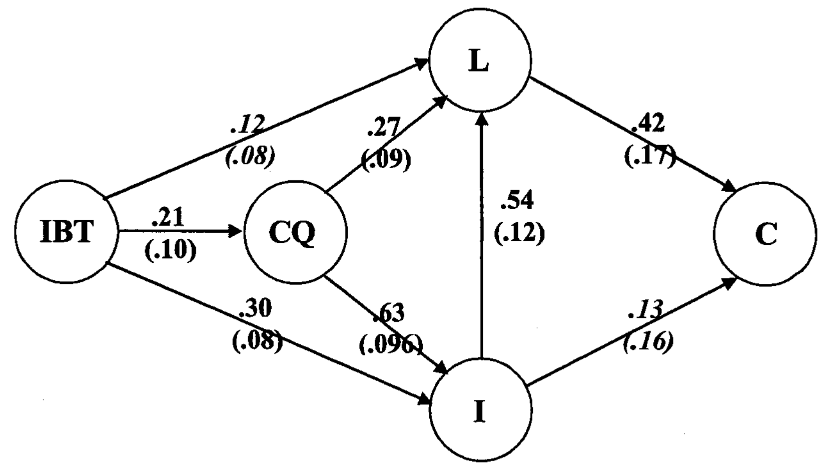


$\chi^2 = 1090.70$ df = 801 $RMSEA_C = 0.052$ n = 132

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.53(.10)	----	.53(.10)	29%	29%
IBT→L	.33(.10)	.32(.08)	.65(.12)	43%	71%
IBT→I	.15(.11)	.30(.08)	.44(.11)	20%	42%
IBT→C	----	.29(.09)	.29(.09)	7.9%	29%

Development Cost: Model for Small Teams



$\chi^2 = 1106.63$ df = 801 $RMSEA_C = 0.051$ n = 145

Effect of IBT use on the other variables in the model:

Variable	Direct Effect	Indirect Effect	Total Effect	R^2(IBT)	R^2(model)
IBT→CQ	.21(.10)	----	.21(.10)	4.3%	4.3%
IBT→L	.12(.08)	.29(.08)	.41(.11)	17%	69%
IBT→I	.30(.08)	.13(.06)	.43(.11)	17%	55%
IBT→C	----	.23(.06)	.23(.06)	6.2%	33%

Figure 8.15 IBT use and development cost: moderating role of team size

Table 8.5 Hypothesis testing: large teams versus small teams

	Model of Product Quality					Model of Time-to-Market					Model of Development Cost					
	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	B1	SE(B1)	B2	SE(B2)	Z	
IBT→CQ	.53	.10	.21	.10	**2.26**	.54	.11	.19	.10	**2.35**	.53	.10	.21	.10	**2.26**	S
CQ→Integration	.56	.12	.63	.10	**-0.45**	.55	.12	.63	.10	**-0.51**	.56	.12	.63	.10	**-0.45**	NS
CQ→Learning	.26	.10	.29	.10	**-0.21**	.25	.10	.29	.10	**-0.28**	.26	.10	.27	.09	**-0.07**	NS
IBT→Integration	.14	.11	.29	.08	**-1.10**	.15	.11	.28	.08	**-0.96**	.15	.11	.30	.08	**-1.10**	NS
IBT→Integration(T)	.44	.11	.42	.10	**0.13**	.45	.11	.40	.10	**0.34**	.44	.11	.43	.11	**0.06**	NS
IBT→Learning	.34	.10	.12	.08	**1.72**	.34	.10	.11	.08	**1.80**	.33	.10	.12	.08	**1.64**	S
IBT→Learning(T)	.66	.12	.41	.11	**1.54**	.66	.12	.39	.11	**1.66**	.65	.12	.41	.11	**1.47**	NS
Integration→Learn	.41	.10	.56	.12	**-0.96**	.42	.10	.57	.13	**-0.91**	.42	.10	.54	.12	**-0.77**	NS
Integration →Quality	.28	.14	.12	.15	**0.78**											NS
Learning→Quality	.46	.15	.67	.17	**-0.93**											NS
IBT→Quality(T)	.42	.09	.32	.08	**0.83**											NS
Integration →Time						.24	.15	.15	.17	**0.40**						NS
Learning→Time						.32	.19	.25	.17	**0.27**						NS
IBT→Time						.04	.14	.26	.10	**-1.28**						NS
IBT→Time(T)						.36	.11	.42	.10	**-0.40**						NS
Integration →Cost											.45	.17	.13	.16	**1.37**	NS
Learning→Cost											.14	.16	.42	.17	**-1.20**	NS
IBT→Cost(T)											.29	.09	.23	.06	**0.55**	NS

- B1 and SE(B1) are values obtained for the models estimated for projects executed by large teams
- B2 and SE(B2) are values obtained for the models estimated for projects executed by small teams
- (T) indicates total effects
- S indicates a significant difference between two groups, NS indicates a non-significant difference between two groups

- The total effect of IBT use on effectiveness of team learning is significantly higher in case of projects executed by large teams than in case of projects executed by small teams – however, this finding is confirmed only by one out of three pairs of models that were estimated. Also, in case of projects executed by small teams the path from IBT use to effectiveness of team learning is not significant.
- There are no significant differences between the two groups in terms of IBT use impact on team integration, product quality, time-to-market and development time

8.6 Other Moderating Variables

The proposed model also included three more moderating variables, namely environmental uncertainty, product complexity and team stability. Preliminary investigation of these variables indicated lack of a clear way of dividing the sample into two distinct groups based on each of these variables. Usually, one subset would include too few cases to conduct a valid analysis. Analysis of the proposed models in different sub-groups of the sample based on these three variables did not indicate any significant and obvious differences or findings as compared to the main models that were estimated and described in Sections 7.1-7.3. Therefore, the results of this preliminary investigations are not reported here and the role of the environmental uncertainty, product complexity and team stability will be investigated in more detail in the future research.

CHAPTER 9

DISCUSSION AND RESEARCH IMPLICATIONS

This chapter presents a discussion of the findings of this study in the context of their contribution to research and practice. The qualitative data (i.e., managerial comments) collected in this research are examined in detail and discussed together with the major findings.

9.1 Introduction

The objective of this study was to investigate the relationship between Internet-based technologies and NPD performance in order to better understand and explain the potential improvement of NPD performance that could be achieved through the use of Internet-based technologies in different areas of NPD activity. In order to meet the stated objective, several questions were researched in detail:

1. What is the nature and extent of the use of Internet-based technologies during new product development projects?
2. What is the impact, if any, of the use of Internet-based technologies in NPD project on project team integration, effectiveness of team learning, and communication quality?
3. What is the impact of team integration and effectiveness of team learning on NPD performance?
4. How does the relationship between the use of Internet-based technologies during NPD project and NPD performance change across different levels of environment uncertainty, product characteristics, and project team characteristics?

Based on an extensive review of the literature a research model was developed proposing that IBT use has a positive impact on NPD performance. It was further hypothesized that this impact is indirect and takes place through improvement of communication quality, effectiveness of team learning and team integration that can be achieved through IBT use to support NPD activities. Also, several contextual factors that could affect the strength of the investigated relationships were identified.

The research conducted for the purpose of this thesis provides answers to all the investigative questions posed and makes a significant and original contribution to knowledge in the area of new product development in a number of ways. At the same time it provides valuable insights for practitioners involved in new product development activities.

9.2 Construct of Internet-Based Technology Use

First of all, in order to investigate the role of the Internet-based technology use in NPD, a construct of IBT use in NPD needed to be defined and a measurement model for it had to be provided. Previous research did not answer this need in a satisfactory way. Existing conceptualizations and measurement models of IBT use are narrow in their scope and usually provide overview of technologies that are implemented and used in an organization. In this thesis a novel conceptualization and definition of IBT use construct was proposed. Internet-based technology use in NPD project was defined as the extent to which the project team deploys Internet-based technologies to support NPD project activities and processes. IBT use was conceptualized as a four dimensional construct, each of the dimensions reflecting a domain of application of the technology. It encompasses data and information management, collaborative team work, external partner/supplier/customer involvement and project management and control. This new conceptualization of IBT use proposed in this thesis provides several benefits: reflects the wide variety of Internet-based technology applications across NPD projects in different industries, reflects that applications may be internally or externally focused, and recognizes that specific project teams might choose to emphasize particular types of applications given the nature of the project or their experience with Internet-based technology. Validity of this approach was further reaffirmed by the comments made by the respondents, indicating that they in fact were using different functionality of IBT and it changed depending on their projects and the context these projects were executed in:

- Internet based technologies used were mainly email correspondence with out of town suppliers. Email also beneficial for exchange of technical data, design information.
- Internet was mostly used for emails and data acquisition/research. Also many files were shared using the Internet.
- Email of messages and attachments was heavily used and was a crucial part of the project. Mainly for the drawings specifications, designs, etc. Daily communications and activities were coordinated by email or usually telephone conference.
- This project was our first using Solidworks CAD. It has good collaboration/info sharing built in when used over our network. The only internet access was used by our Operations Manager who works remote from an location. He was able to monitor our progress by looking at our Solid Models by VPN.
- There are many creative ways to apply IBT technologies in meeting product development objectives. Further, they are very flexible in accommodating a full range of business and development environments.

- This project involved a great deal of data collection. At completion of that phase the information reports were developed and shared via email mostly with videoconferences for team members from up to 4 sites in Canada and the USA. Team members performed assigned tasks on a compartment basis. Primarily dueto culture.
- All of our design data is managed by computers. However, most communication is email and meetings (including teleconferences). We are working on some Internet based data transfer solutions. At present, data is sent by e-mail or on CD in the mail. We hope to change this within the next few months after the systems are running. We do have access to some data we receive for use in development that is pulled from an intranet within the corporation.
- Internet is usually used to learn about competitors products and customers generic interest. Also extensively used for engineering literature research (IEEE) and patent searches. Email is used for specific customer/vendor communications. The company's internal intranet is used for document and test results storage and retrieval among team members.

The comments made by the respondents confirm the validity of the multi-dimensional conceptualization of IBT use. It is visible that different projects used different functionality of IBT across the proposed dimensions of data and information management, collaborative work, external partners involvement and project management.

The contribution of this thesis is not limited to proposing a new and valuable conceptualization of IBT use, but also encompasses providing a measurement model for IBT use construct. The measurement model was developed based on an extensive literature review and a series of discussions with industry specialists and then statistically tested based on the collected data. The resulting revised measurement model of IBT use in NPD has very high reliability and validity and can be applied in further research.

9.3 Relationship between IBT Use and NPD Performance

The main objective of this research was to investigate the relationship between IBT use and NPD performance. The positive impact of IBT use on NPD performance is widely postulated in the academic literature in the NPD field (e.g., Howe *et al.*, 2000; Mathieu, 1996; Sethi *et al.*, 2003; Ozer, 2004). It is also widely supported by practitioners, including a large number of the participants of this study who provided the following comments in the open-ended section of the questionnaire:

- In this day and age it is unthinkable that new products could be developed without the use of the Internet. Products are better and developed more efficiently because of Internet tools usage.
- Internet is the most cost-effective way to communicate externally with vendors, partners and customers.
- As a small division located in a small town in Southern Ontario, Internet connections to our parent company and suppliers were very important. Overall virtual "NET" meetings proved very important. Also "project place" concepts were important.
- Internet-based email and user forums provide valuable information about customer needs; internal communication and file sharing speeds the development process; email based communication and transfer of drawings allows local and offshore resources to be effectively incorporated in the design and development program.
- Email is definitely the biggest time-saver as far as immediate communication. Sending CAD data over the Internet saves a tremendous amount of time off project development especially when suppliers are overseas.
- Internet usage has greatly reduced design problem resolution.
- Internet gives the ability to communicate around the world exchanging ideas and drawings quickly. Enables companies to respond to ever-changing requirements by customers. From concept to delivering a finished product the ability to meet customers demands is increased tremendously by use of Internet based technologies.
- Email reduced the need for travel for face-to-face meetings.

- Communication, data management, project management and collaborative analytical tools shared over networks definitely support more effective product development.

- We use Windchill PDM Link as our Engineering database. With it manufacturing can use it to view and print drawings on their own without having to rely on R&D's blue print machine. We are saving time in printing and copying data between sites. (Manufacturing is located at 3 sites separate from R&D / Engineering). We also use Baan collaborate Product Structure throughout the company.

- Fast, easy exchange of information and changes to that information in many forms, verbal, written, data and 3D.

- Great help was 1) by using suppliers with web sites having good specifications for components plus 2) ability to order parts on line for fast delivery of prototype components 3) ability to share specs and reviews quickly by email.

- E-mail with China very useful, with 12 hours time difference it's difficult to have telecons or video conferences due to this time difference but e-mails are great; you email before leaving work for the day, and when you get in the next morning you have responses... work on these for the day...email before leaving...

- Quick access to design tools, data sheets and samples.

Despite the general agreement on the potential benefits of IBT use in NPD projects, the relationship between IBT use and NPD performance has not been empirically tested in great detail before this study was conducted. As one of the respondents indicated, practitioners are still in need of better understanding of the benefits that can be achieved through the use of Internet-based technologies and see justification for investment in these technologies:

- We have looked at the software available to help improve NPD data sharing. It always came down to it: Is it worth it? We were never able to justify the purchase of a tool, i.e. Team Center, Windshill.

Although there is a number of studies devoted to the role of IT, and ICT in particular, in new product development projects, none of them addressed this issue in the way it was done in this research. This research significantly contributes to a better understanding of the relationship between IBT use and NPD performance because of its several features not present in previous studies: it applies the proposed conceptualization of IBT use as a four dimensional factor addressing different domains of IBT applicability/functionality; it compares the role of IBT use across different NPD performance dimensions (namely product quality, time-to-market, and development cost); it investigates and compares the impact of different dimensions of IBT use on NPD performance; and, through investigation of the role of three intervening variables (communication quality, team integration and effectiveness of team learning), it examines the indirect nature of the impact of IBT use on NPD performance. Additionally, this research provides preliminary analysis of the impact of several moderating variables on the relationship between IBT use and NPD performance in order to identify the conditions under which the impact of IBT use on project performance may be more pronounced.

As a result of the performed analysis, the hypotheses about the positive impact of IBT use on product quality, time-to-market and development cost were confirmed. At the same this research indicated that the positive impact of IBT use on NPD performance is indirect and takes place through two channels: improvement of the effectiveness of team learning, and improvement of team integration. Communication quality plays important role as a predecessor of the impact of IBT use on effectiveness of team learning and team integration. As compared to the proposed model, this research also found a positive relationship between team integration and effectiveness of team learning which was not originally hypothesized. It has also found a direct link between IBT use and time-to-market. However, it also confirmed that there are no direct links between IBT use and product quality and between IBT use and development cost. The direct link between IBT use and time-to-market is supported by the existing literature and practitioners' comments. Time reduction can be achieved directly through IBT use in many ways that are inexpensive and straightforward to implement: communicating with other team members through e-mail, e-mailing documents and sharing data over the Internet, etc. As one of the respondents pointed out "e-mail is definitely the biggest time-saver as far as immediate communication".

This research investigated the nature of the impact of IBT use on NPD performance in more detail than it was ever done before. Given the nature and definition of the Internet, its main characteristics is the connectivity it offers to its users. This research confirmed that the Internet-based technology use directly contributes to communication quality. Next, it indicated that IBT use affects effectiveness of team learning and team integration not only directly, but also indirectly, through the improvement of communication quality. In summary, the effect of IBT use on effectiveness of team learning is taking place through multiple channels: directly, though improvement of communication quality and through improvement of team integration.

When the relationship between IBT use and product quality is considered, there is no direct effect between these two variables. IBT use has only indirect impact on product quality, which can be realized through the improvement of communication quality, effectiveness of team learning and team integration. Product quality depends on many factors. One of the most important of them is effectiveness of team learning, i.e. information acquisition, knowledge sharing and application. Therefore, in order to improve product quality through the use of IBT, the technology needs to be successfully applied to support team learning or its predecessors, i.e. communication quality and integration.

In case of the development cost, a stronger relationship between IBT use and reduction of development cost was expected. However, there are several possible explanations. In order to understand it, it is important to break the development cost into several categories: the cost of coordination of activities, the cost of performing the activities, such as prototyping etc. It appears that the development cost consist to large degree of elements that are not very easily reduced by IBT use: engineers' work time, materials, etc.

9.4 Factors Affecting the Role of IBT Use

Another very important finding and contribution of this research is confirmation that the need for IBT and the role of IBT during the life of a development project differs significantly given the nature of the project and other contextual factors. In one of the questions on the questionnaire, the respondents were asked to indicate their level of agreement (on a 5-point scale) with the following statement: "This NPD project would not be feasible without the use of Internet-based technologies". The collected responses indicated wide range of possible impact of IBT on the feasibility of a project: out of the 270 responses to the above question, 77 respondents (28.5%) indicated that they agree or strongly agree with the statement, while 152 (56.3%) respondents answered that they disagree or strongly disagree it. The remaining 41 (15.2%) respondents indicated that they neither agree or disagree. These responses indicate that there was quite a high number of projects where the use of IBT was a necessary condition of undertaking the project at all. It is in accordance with some of the academic literature indicating that in some projects IBT use is becoming a necessary (but not sufficient) condition of success. This finding was also reaffirmed in some of the comments received from the respondents:

- This project would not be feasible without the use of Internet-based technology.
- IBT was essential for this joint development effort. Problems encountered were due to the complex project and technology issues. Use of IBT helped alleviate time-zone and cultural/language barriers in dealing with foreign supplier/partner, however, could only reduce these limiting factors. This project would not be attempted or possible without IBT. The use of IBT enabled the project to be conceived and executed.

However, there are also projects where IBT use does not play so significant role or does not play a significant role at all. This research provides some insight into the factors that affect the role of IBT during execution of a development project. First of all, the respondents themselves indicated a number of projects which did not require IBT use or during which IBT use played only marginal role:

- Materials development is an experimental program based in a single location. Internet technologies not required.
- Because this project involved the redesign of a unique product which uses proprietary and patented technology, Internet based technologies did not play a big part on this project.
- Very little work or design done through internet, as most hands-on and design done at our facility.
- Due to this particular firm, Internet based technology does not play as critical of a role as for other companies.
- Because we are small and are communicating mostly amongst ourselves and the end users (mining personnel) we do not have much use of formal internet based channels of communication except for email which we rely on heavily and almost exclusively.
- Our development teams work very closely together in a central location so we don't rely as heavily on internet technologies. We have one new development starting out with a links for collaboration/information sharing. This particular development involves people in many different locations so we needed something.
- Project collaboration across the internet works well for programs shared across company divisions. For smaller application based new product activities, activity is focused on communication tools - email, conferencing
- All of the team members except customers and an occasional consultant are in the same location. If we had manufacturing and engineering in different locations, the use of the internet would be much higher.
- Our project team is small and located at one facility so the use of the internet for internal team management is not necessary.

The comments provided by the respondents indicate belief that especially the projects that are conducted by small teams and/or teams that are collocated, do not require extensive use of Internet-based technologies and that these technologies will not have much impact on NPD performance of such projects.

When a preliminary analysis was conducted for projects involving unfamiliar technology versus projects involving familiar technology, the results were not indicating significant difference in the strength of the relationship between IBT use and NPD performance. This finding seems to indicate that technology novelty does not affect the relationships between the variables of interest. However, it has to be recognized that the relationship between technology novelty and NPD performance may be more complex and contingent on other factors. For example, other team characteristics, such as team dispersion or team diversity could interact with technology novelty.

9.5 Other Findings

One very interesting finding was that the use of IBT in a given project is not constant over time, but evolves, as different functionality plays more important role in different stages of the project. This was indicated by the managers:

- Internet based technologies were used during the research and development phase of the project to gather data on competitor models. Once the manufacturing phase starts, we work closely with the customers and suppliers to maximize performance - face to face meetings or on phone. No internet or email used.
- Our internet based technologies evolved during the same time as this project. What started as server based information located at facility, transferred back and forth via email, finished as a Web based work place supported by email and web based video conferencing.

The changing needs for IBT were also postulated in the academic literature by, among others, Ozer (2003) who developed theoretical model of the Internet's role in the different stages of the NPD process. He distinguished among nine NPD stages and identified different benefits offered by the Internet at each stage.

Additionally, this study has also identified a number of difficulties and challenges related to the use of IBT by the respondents. These difficulties significantly affect the relationship between IBT use and project performance. In order to benefit most from IBT use, project teams using these technologies in their work need to overcome numerous technical or organizational difficulties related to the implementation and adoption of the technology. The respondents highlighted the following challenges that have hindered the benefits that could have been otherwise gained through the use of Internet-based technologies:

- Our significant difficulty was the severe content restrictions enforced by our IT department. Many developer blogs cannot be accessed - including Microsoft ones! Similarly some support sites using AJAX would not operate correctly.
- We experienced difficulties because of design teams at different locations using different CAD systems.
- Internet connection is not very stable, was experiencing network issue, packet loss, high-ping, lagging etc.
- Some websites do not have the product information readily available. Sometimes it is difficult to download a 3-D model of a manufacturers part. Or if you search for a part by exact part number, the website can not find it, even though you know it is there.
- Web-based videoconferencing hampered by internal firewall rules - could have sped up design reviews and project status reviews with customers.
- 1) most internet based technologies are customer program requirements (mandated) 2) confidentiality of data is a major concern 3) data being transferred must be in native format specified by customer 4) we deal with Ford and GM, the biggest challenge that we have is that all of our customers use different CAD packages (I-deas, pro/e etc).

- Lack of information and/or affordable software for small companies. Eg. Celestica (former Toronto IBM) they do have Lotus Notes for internal communication, however, is there any affordable software for small or medium scale companies? Another important issue is a standard format of archiving and saving info.
- Our industry is slow moving and tends to be adverse to new technology.
- We could have used more internet based technologies but had some restrictions internally.

Overcoming of technological difficulties would improve the benefits obtained through IBT use. However, it still would not guarantee high project performance, because as this research has indicated, IBT use is not the sole determinant of NPD performance (it explains only a given percentage of NPD performance). There is a number of other factors that contribute to project performance or that are necessary condition of a success. The respondents indicated the following factors of critical importance for NPD performance whose lack was often the main reason of poor performance of a project:

- Personality, organizational structure and divergent goals limited team cohesion.
- Although project would have increased revenue by 50% for company, there was little senior management support and board of directors was not informed of project plans.
- Key project leader transferred during the project. His replacement, a new hire, did not work out and left after a year. That was very costly and extended the project by at least 9 months to a year.
- The input from marketing was requested but never received.
- Problems encountered were due to the complex project and technology issues.
- These technologies do not ensure a well coordinated team development. They can however facilitate one if the team uses them properly and makes the proper efforts to be coordinated.

- Internet does not team build, if you have a bad team the internet will not improve team work.

- Key learning: E-mail does not work for discussion of problem issues and communication must occur face to face several times. In fact, we now start international development efforts with face-to-face meetings and continue those every 6 months because while you can share information via email, you cannot really communicate via email. We have weekly phone calls which are compulsory with staff removed from the central location. The key to success is the relationships amongst the people.

- Better project control methods were needed to control costs and schedules. The most important issue was co-ordination and communication between team members!

It has to be therefore recognized that although both the quantitative and qualitative analysis conducted for the purpose of this thesis indicated significant contribution of IBT use to NPD project performance, this contribution depends on a number of contextual factors and IBT use is not a sufficient condition to guarantee high project performance.

The analysis and findings of this study allow to formulate several important recommendations for managers of new product development projects. First of all, this study confirms that the use of Internet-based technologies in NPD has a positive impact on NPD performance in terms of time-to-market, product quality and development cost. Therefore, an investment in Internet-based technologies can be seen as a possible way of performance improvement. However, before the decision about adoption of the IBT technology can be made, several questions should be first answered. The managers considering implementation of IBT should first analyze the nature of their NPD activities and the possible range of IBT functionality. This study indicates that the role of IBT in new product development differs significantly based on the nature of the development project, type of product being developed and the team that is executing the project. Managers should be therefore made aware that they need to understand the context of their project very well before making decisions regarding IBT use. IBT have very wide range of functionality and its different aspects prove to be important in case of different NPD projects.

CHAPTER 10

CONCLUSION

10.1 Summary of the Research Findings

This study made some novel contribution to the understanding of the impact of Internet-based technologies on NPD project performance. It is often hypothesized in the literature that IBT contribute directly to NPD project performance. However, this study shows that although project time-to-market is directly affected by IBT use, the impact of IBT on NPD performance dimensions is mostly (and in case of product quality and development cost exclusively) indirect and takes place through improvement of team communication quality, effectiveness of team learning and team integration.

The research conducted for the purpose of this thesis indicates that although implementation of Internet-based technology itself creates opportunity for significant performance improvement, it is not a sufficient condition of achieving this improvement. Two things have to be taken into consideration, before the benefits from IBT use can be realized. First, it is important what technology is adopted and to support what activities. This research investigated four dimensions of IBT use in NPD projects and the findings suggest their different role in contributing to different types of performance. Second, the adoption of Internet-based technology in isolation from the organizational and managerial context of a project is insufficient to exploit all the potential benefits that can be derived from the use of it. As a result, lack of performance improvement after implementation of information technologies is not, in many cases, due to technical reasons, but rather to a lack of proper organizational and managerial context.

Overall, this research represents an effort aimed at building a comprehensive theory and a model for understanding how the impact of IBT use on NPD performance is taking place and can be strengthen. The results of this study are particularly important for encouraging and supporting the management of Internet-based technologies within NPD projects from a new perspective. This perspective recognizes different needs of different projects as well as different dimensions of IBT use and its links to NPD performance.

10.2 Limitations of the Study

Although the findings of this study support majority of the proposed hypotheses, the results must be treated with caution due to some inherent limitations of the analysis. This is related to certain issues with regards to research design, data collection and generalizability of the results.

First of all, there is a chance of a potential non-response bias. The data analyzed in this research were collected by the means of a survey. The value of a survey in addressing the research questions depends on individuals participating in the research effort. Given the response rate of 12.6% in this study, there is a risk that the respondents are not representative of the population being studied, resulting in the nonresponse bias.

The differences between respondents and nonrespondents (nonresponse bias) may affect the relationships among the variables being studied (Sackett and Larson, 1992) and lead to reduced external validity and misleading conclusions that do not generalize to the entire population (Rogelberg and Luong, 1998). Even with a large response rate, a number of phenomena (e.g., volunteer bias) may affect who responds to a survey, creating differences between respondents and nonrespondents beyond sampling error (Roth and BeVier, 1998; Viswesvaran *et a*l., 1993).

Several approaches have been proposed to test for nonresponse bias (Rogelber and Luong, 1998). In order to address this concern for the purpose of this thesis, the following steps have been undertaken. First, efforts were made to increase the number of respondents by follow up emails and phone calls encouraging participation in the study and investigating the reasons for nonresponse. As a result, the final response rate in this study is comparable to the average response rate usually achieved in other research on new product development in high-tech industries. Second, the respondents were compared to the nonrespondents on variables that were known from the databases, such as company size and industry. This comparison did not detect any significant differences between respondents and nonrespondents. Also, follow-up analysis was undertaken when nonrespondents were asked for the reasons of their nonresponse. The follow up phone calls and interviews indicated that most of the nonrespondents were passive in nature and did not create bias, because as a general rule they seem to be willing to participate in filling out the survey. One of the major reasons of nonresponse quoted by nonrespondents was the fact that in the recent past they have already received and filled out a different survey and were not able to, because of time constraints, fill out the next one. It can be expected that this group of nonrespondents does not differ from the respondents in any significant way that could distort the findings from this study. However, the concern about the nonrespone bias should be further investigated. One of the recommendations for future research is therefore to replicate the findings of this study across multiple data samples in order to demonstrate their generalizability.

Another concern related to this study is the common method variance (Podsakoff *et al.*, 2003). It is widely argued that correlations between variables measured with the same method, usually self-report surveys, are inflated due to the action of common method variance. The concern is related to the fact that the use of one respondents to answer all the questions leaves many alternative explanations for observed correlations other than the intended traits are related. As a result, it does not allow for confident causal conclusions. In order to estimate the common method variance and its impact on the results, it is important to understand the constructs, the method and the motivation of participants. Method effects are motivational in nature, though the motivation may not be easily articulated or understood even by respondents. Analysis of the topic of this study and the respondents indicates that the method effects should not play a significant role in the conducted data collection. Also, self-report cross-sectional questionnaires are considered a valuable and relatively easy first step in studying phenomena of interest (Podsakoff *et al.*, 2003). Once the preliminary investigation (as the one conducted in this study) is completed, the researchers should move to other methodologies to further test self-report studies and theories. It is however important to realize that certain conclusions cannot be drawn as well as the results cannot be overgeneralized and overinterpreted.

Another concern, apart from the nonresponse bias, is related to the sample size and whether it is sufficient for conducting the analysis. Researchers explaining SEM requirements (Kline, 2003) suggest that the sample size necessary for estimation of moderately complex models such as the one in this study should be between 200 and 300 cases. Therefore, the main analysis conducted in the study can be considered valid. However, given the fact that the collected data were divided into two sub-samples when the analysis of moderating variables was conducted, the obtained results of this analysis should be treated as only a preliminary investigation and retested with larger sub-sample sizes.

Another important concern is sample and generalizability. This research focuses on organizations operating in specific industries and a specific geographic area. Also, it addresses only organizations that have more than 25 employees. As a result, the findings of this study may have limited generalizability to companies that are not within the same industries or are not operating at the same geographical area or are very small (i.e., size <25 employees). Future research should focus on expanding this research in terms of both industrial and demographic scope.

Next, the empirical data which was a basis for accepting or rejecting the model and the hypotheses implied by the model, was derived from participants' self report and perceptions. In particular, the validity and reliability of the instruments used to measure the constructs depended upon the respondents' knowledge of the facts. Future studies are needed to further test the validity and reliability of these measures.

Finally, the measurement instrument of Internet-based technology use was completely new and was never proposed in previous research in the same form. In order to develop measurement model for IBT use construct, the existing literature was compiled and analyzed as well as practitioners' opinions were collected. As a result, this instrument needs additional testing in different environments.

Despite the limitations, this study makes an important contribution to the current boy of knowledge about the relationship between Internet-based technology use and NPD project performance.

10.3 Recommendations for Future Research

There is a number of future research directions that could be undertaken to provide better understanding of the relationships investigated in this study. First of all, the instrument of IBT use should be further tested in order to verify its validity and reliability in different settings. Also, two more aspects of IBT use could be captured in future studies: IBT use across different stages of projects and the level of integration of different information systems related to NPD and used by the project team. Second, this research does not look at the organizational level. In the future research it would be interesting to look at NPD projects in the context of a company's R&D activity and knowledge transfer between different projects.

Examining the final model it is plausible that feedback loops may exist between various components of the research model. Especially the link between team learning and communication as well as link between team integration and communication quality could be investigated in more detail. For example, it is plausible that team integration influences communication quality. Further research should attempt to test these relationships.

The final model explains only 12% of the variance in communication quality. Since the role of communication quality is critical as a transmitter of the IBT influence on performance, it would be a recommended future research to expand the model so it will address the factors contributing to communication quality and see their interactions with IBT use.

Team learning and team integration are multi-dimensional constructs. In its present form, the model does not explain the impact of IBT on different dimensions of these variables. It is very likely that the impact of IBT on functional integration may be very different from IBT impact on social integration. This could be investigated in future research.

Several questions about performance were asked of managers to evaluate the project's performance as compared to the goals set the beginning of the project. However, there is a concern that managers may set stricter goals in return for committing the resources required to implement Internet-based technologies. Therefore, the resulting performance may be lower, because there were high expectations/goals of performance given that the project managers were planning to use the Internet-based technologies. It would be an interesting area of future research to investigate whether and how the implementation of the technology affects the managerial and employee expectations of product development activities and performance.

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Appendix A Definitions and measurement of variables

DEFINITION	MEASUREMENT TOOL	REFERENCES
	NPD Performance The effectiveness and efficiency of new product development effort (Cordero, 1989)	
Product Quality The degree to which a product's performance, attributes, or features satisfy customer requirements (Clark and Fujimoto, 1991)	1. Please rate your product quality as compared to quality goals at the start of the project. 2. Please rate your product quality as compared to quality of similar past products in your organization. 3. Please rate your product quality as compared to quality of similar competitor products. 1= significantly inferior; 3= about the same; 5= significantly superior	Kessler and Chakrabarti (1998)
Time-to-Market A time measure of the pace at which the product was developed by the team (Sarin and McDermott, 2003)	1. Please rate the time taken to develop and launch this product as compared to time expected at the start of the project. 2. Please rate the time taken to develop and launch this product as compared to time taken to develop and launch similar products in your organization in the past. 3. Please rate the time taken to develop and launch this product as compared to time taken to develop and launch similar products by your nearest competitors. 1= much longer; 3= about the same; 5= much shorter	Kessler and Chakrabarti (1998); Sarin and McDermott (2003)
Development Cost The total financial requirements and associated human resources needed to complete the project (Rosenthal, 1992)	1. Please rate the total project cost as compared to the budget goal. 2. Please rate the total project cost as compared to the total cost of similar past projects in your organization. 3. Please rate the total project cost as compared to the total cost of similar projects executed by your nearest competitors. 1= much higher; 3= about the same; 5= much lower	Kessler *et al.* (2000)

DEFINITION	MEASUREMENT TOOL	REFERENCES
	Team Integration The degree of unity of efforts among the team members in the accomplishment of the project's goal (Lawrence and Lorsch, 1967b) three-dimensional construct composed of functional, normative, and social integration (Feldman, 1968)	
Functional Integration The degree of coordination of group members' activities required to progress towards the goal (Feldman, 1968)	1. Activities performed by different project team members were well coordinated. 2. The resources were allocated within the team effectively. 3. Project team members were assigned to tasks matching their knowledge and skills.	Malone and Crowston (1994) Crowston and Kammerer (1998) Mohr and Spekman (1994)
Normative Integration The degree of consensus among group members concerning a number of group-relevant behaviours and norms (Feldman, 1968)	1. Project team members had common vision and goals. 2. Project team members shared resources to complete tasks. 3. Project team members achieved goals collectively. 4. Project team members worked together as a team. 5. Project team members sought integrative solutions.	Koufteros *et al.* (2005) Kahn and Mentzer (1996)
Social Integration The cohesiveness of the group, i.e. reciprocal liking and attraction among group members (Feldman, 1968)	1. Project team members recognized each other's talents and expertise. 2. Project team members were likely to defend each other from criticism by outsiders. 3. Project team members helped each other to more effectively perform their tasks. 4. Project team members got along well with each other. 5. Project team members perceived their problems as mutual problems.	Seashore (1954)
	Effectiveness of Team Learning Effectiveness of team processes of information acquisition, knowledge sharing, and application (Lynn *et al.*, 2000)	

DEFINITION	MEASUREMENT TOOL	REFERENCES
Information Acquisition effectiveness of the process of acquiring and storing required and relevant information for product development	1. The project team displayed a high level of competence in acquiring the information needed to develop the product. 2. The project team acquired the information needed to develop the product from a variety of sources. 3. The project team gathered sufficient relevant internal and external information regarding customers, markets, technologies, and competitors during the project. 4. The project team organized and stored the information generated during the process in a meaningful way.	Akgün *et al.* (2002) Brockman and Morgan (2003)
Knowledge Sharing consensus on the meaning of the information and its implication for the project	1. The project team was successful at distributing information needed for task completion among the team members. 2. Project team members were well aware of where specialized knowledge is located and needed in the project. 3. Project team members had good insight of what everybody else involved with this project was doing. 4. Project team members developed a similar understanding of the role the acquired information would play in developing the product. 5. Project team members openly shared their ideas with each other.	Brockman and Morgan (2003) Akgün *et al.* (2002)
Knowledge Application effectiveness of the processes of information utilization for decision making and problem solving	1. During the project, the product development process improved. 2. The project team had the ability to incorporate lessons learned during the project into the final product. 3. The project team had the ability to translate customer needs into product design specifications. 4. The project team was able to effectively respond to changes in customer needs. 5. The project team was able to effectively respond to changes in technological environment. 6. The project team was very good at joint problem solving.	Akgün *et al.* (2006) Akgün *et al.* (2002)

DEFINITION	MEASUREMENT TOOL	REFERENCES
	Communication Quality The degree to which relevant and understandable information reaches the intended information receivers in time (Lievens and Moenaert, 2001)	
Communication Quality	1. Communication among team members was timely. 2. Communication among team members was reliable. 3. Communication among team members was open. 4. Communication among team members was accurate. 5. Communication among team members was effective.	Mohr and Spekman (1994)
	Internet-Based Technologies Use The extent to which the project team deploys Internet-based technologies to support NPD project activities and processes	
Data and Information Management	Please indicate the extent to which Internet-based technologies have been applied by the project team members to support the following activities: 1. Access and request product data and other information 2. Collect, store, categorize, and retrieve data and other information 3. Exchange messages with one another 4. Send, forward, receive, and reply to messages from other team members 5. Exchange files or documents with one another	Boynton *et al.* (1994) Busch *et al.* (1991) Corso and Paolucci (2001) Lewis *et al.* (2004) Ozer (2003, 2004) Kessler (2003) Sethi *et al.*(2003)
Collaborative Team Work	Please indicate the extent to which Internet-based technologies have been applied by the project team members to support the following activities: 1. Conduct virtual meetings of distributed team members 2. Provide virtual work environment for sharing resources and information 3. Providing virtual work environment for performing activities jointly and simultaneously 4. Provide real-time or near real-time communication among team members	Boynton *et al.* (1994) Busch *et al.* (1991) Corso and Paolucci (2001) Ozer (2003, 2004) Kessler (2003) Sethi *et al.*(2003)

DEFINITION	MEASUREMENT TOOL	REFERENCES
External Partner Involvement	Please indicate the extent to which Internet-based technologies have been applied by the project team members to support the following activities: 1. Communicate and exchange ideas with external partners/suppliers/customers 2. Obtain inputs and feedback from partners/suppliers/customers 3. Provide data sharing with external partners/suppliers/customers 4. Enable participation of external partners/suppliers/customers in virtual work environment	Boynton *et al.* (1994) Busch *et al.* (1991) Corso and Paolucci (2001) Lewis *et al.* (2004) Ozer (2003, 2004)
Project Management and Control	Please indicate the extent to which Internet-based technologies have been applied by the project team members to support the following activities: 1. Coordinate activities performed by team members 2. Support project go-kill decision making 3. Monitor project schedule and budget 4. Conduct performance monitoring and assessments 5. Perform risk management activities	Boynton *et al.* (1994) Busch *et al.* (1991) Corso and Paolucci (2001) Lewis *et al.* (2004) Ozer (2003, 2004) Kessler (2003)
	Moderating Variables	
Environmental Uncertainty The rate of change in technology and market (Jaworski and Kohli, 1993)	1. The technology in the industry had been changing rapidly during the execution of the project. 2. Customers' preferences/requirements changed quite a bit during the execution of the project.	Jaworski and Kohli (1993) Akgün *et al.* (2006)
Product Innovativeness Degree of product's newness to the firm and newness to the market (Booz-Allen and Hamilton, 1982)	Five categories of product innovativeness: • New-to-world product • Product line new to the firm • Addition to the firm's existing product line • Major revision to an existing product • Incremental change to an existing product	Booz-Allen and Hamilton (1982)

DEFINITION	MEASUREMENT TOOL	REFERENCES
Product Complexity Number of product parts and their interdependence	1. The number of product parts in this product is very high. 2. Product parts in this product are highly interdependent.	Baccarini (1996) Novak and Eppinger (2001)
Technology Novelty The degree of team members' familiarity with technology in the product	1. The technologies used in this product were new (unfamiliar) to the project team members.	McDonough and Barczak (1992)
Team Functional Diversity Number of departments and external stakeholders represented on the team	Please indicate all the functional areas within your organization and external organizations that were represented on the project team: marketing and sales, purchasing, manufacturing, research and development, engineering/design, customer support, suppliers, customers, partner firms.	Sarin and McDermott (2003)
Team Proximity Geographical dispersion of team members (Carbonell and Rodriguez, 2005)	Please indicate where team members were located: • In one building/office • In several locations, but one city • In several cities, but one country • In more than one country	McDonough *et al.* (2001)
Team Size The number of project team members	Please indicate the total number of project team members from within your company:____ Please indicate the total number of project team members external to your company:____	Sarin McDermott (2003)
Team Stability The membership turnover	1. Most of the project managers and leaders who started this project remained on it from start to completion. 2. Most of the team members who were on the team remained on it from start to completion. 3. Most of the team members were assigned to this project on a full-time basis. 4. Most of the team members worked together on previous development projects.	Akgün and Lynn (2002)

Appendix B List of the proposed hypotheses

The Hypotheses Regarding the Core Model:

Hypothesis 1 Project team integration will positively influence NPD performance.

Hypothesis 2 Effectiveness of project team learning will positively influence NPD performance.

Hypothesis 3 Project communication quality will positively influence project team integration.

Hypothesis 4 Project communication quality will positively influence effectiveness of project team learning.

Hypothesis 5 The use of Internet-based technologies during a development project will positively influence project team integration.

Hypothesis 6 The use of Internet-based technologies during a development project will positively influence effectiveness of project team learning.

Hypothesis 7 The use of Internet-based technologies during a development project will positively influence project communication quality.

Hypothesis 8 The use of Internet-based technologies during a development project will positively influence NPD performance.

The Hypotheses Regarding the Moderating Effects:

Hypothesis 9 The impact of Internet-based technology use on NPD performance will be greater for projects conducted in environments characterized by high uncertainty compared to projects conducted in environments characterized by low uncertainty.

Hypothesis 10 The impact of Internet-based technology use on NPD performance will be greater for highly innovative products compared to less innovative products.

Hypothesis 11 The impact of Internet-based technology use on NPD performance will be greater for highly complex products compared to less complex products.

Hypothesis 12 The impact of Internet-based technology use on NPD performance will be greater for projects characterized by high technology novelty compared to projects characterized by low technology novelty.

Hypothesis 13 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by teams with high functional diversity compared to projects conducted by teams with low functional diversity.

Hypothesis 14 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by highly dispersed teams compared to projects conducted by collocated teams.

Hypothesis 15 The impact of Internet-based technology on NPD performance will be greater for projects conducted by large teams compared to projects conducted by small teams.

Hypothesis 16 The impact of Internet-based technology use on NPD performance will be greater for projects conducted by unstable teams compared to projects conducted by stable teams.

Appendix C Letter of invitation to participate in the study

Dear Sir/Madam:

I am a doctoral student at Eric Sprott School of Business at Carleton University in Ottawa, Canada. I am currently working towards completing my Ph.D. thesis on the role of Internet-based collaboration technologies in new product development in North American manufacturing organizations.

My research focuses especially on the extent to which Internet-based collaboration technologies are currently used by manufacturing companies to support new product development activity and on the impact of these technologies on project performance in terms of speed-to-market, product quality and total project costs. This research will offer theoretical and practical contributions to the area of NPD by verifying and explaining the role of Internet-based technologies in NPD activities and their contribution to NPD performance.

This letter is to kindly request you to participate in my study by completing the enclosed questionnaire and returning it in the envelope provided. Your responses will be kept confidential and will not be disclosed to any outside parties. Anonymity will be ensured by aggregating the results of individual questionnaires when reporting the research findings. The questionnaire should take about 20 to 30 minutes to complete. When completing the questionnaire, you can leave blank any questions that you do not wish to answer. Your response will contribute to the success of this study and will be greatly appreciated.

There are no foreseen risks to the participants of this study. The research findings from this study will be presented in the final Ph.D. thesis report and in a series of papers to be submitted to conferences and academic journals. The data will be stored both in hard copy (filled out questionnaires) and electronic copy (file with all the responses) with only the researcher having access to it. It is not going to be destroyed and might be used for future analysis related to the topic of the present study.

Should you require additional information, please do not hesitate to contact me at 905-637-0097 (voice mail available) or by email: dderegow@connect.carleton.ca. You are also welcome to contact either of my thesis supervisors: Professor Uma Kumar at 613-520-6601 (e-mail: uma_kumar@carleton.ca) or Professor Vinod Kumar at 613-520-2379 (e-mail: vinod_kumar@carleton.ca) for further information.

If you would like a summary of the results of this study, please provide your contact information in the space provided or attach your business card or, if you want your survey response to remain anonymous, contact me in writing, by e-mail or phone.

This research project has been reviewed and approved by the Carleton University Research Ethics Committee. If you have any questions or concerns you may contact the committee chair, Prof. Antonio Gualtieri at 613-520-2517 or ethics@carleton.ca

Thank you very much for your help.

With appreciation,

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Appendix D Questionnaire

Carleton UNIVERSITY

A STUDY OF INTERNET-BASED TECHNOLOGY USE IN NEW PRODUCT DEVELOPMENT

This questionnaire should be completed by project managers or team leaders for new product development projects.

Your response should be based on a particular new product development project in which you were involved and which was completed recently or is near completion. Please feel free to select any project, regardless of its success or disappointing result in the market.

If there are any questions you do not want to answer then please proceed to the next question. Please try to answer all the questions. Your responses will be held in strict confidence. If you wish to receive the summary of research findings, please indicate on the form provided.

Should you require additional information, please do not hesitate to contact me, Danuta Deregowska at 905-637-0097 or by email: dderegow@connect.carleton.ca. You are also welcome to contact either of my thesis supervisors: Professor Uma Kumar at 613-520-6601 (e-mail: uma_kumar@carleton.ca) or Professor Vinod Kumar at 613-520-2379 (e-mail: vinod_kumar@carleton.ca) for further information.

Thank you for completing this questionnaire. Your input is very much appreciated.

Definitions and Interpretations:

A new product development (NPD) project is defined for the purpose of this survey as any project involving the development of a new product, a major change to an existing product, or an incremental change to an existing product. The project may encompass activities from assessment of the product idea to market introduction.

A project team is defined for this survey as a team comprised of all the individuals who were assigned responsibility for completion of one or more project tasks. Team members include all individuals from different functional disciplines (e.g. design, manufacturing, marketing) as well as individuals from other organizations (such as customers, suppliers, partners) who were directly involved as task participants on the project, including project managers and team leaders.

Internet-based technologies are defined widely as web-enabled or Internet-enabled technologies or tools using Internet protocols. They include a variety of electronic communication, information/data management, and collaboration tools (e.g. electronic mail, instant messaging, videoconferencing, Intranets, Internet-enabled project workspaces/systems/tools, distributed virtual networks and file sharing systems, web-enabled groupware, or design or modeling tools for distributed teams etc.).

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PART I: PROJECT CHARACTERISTICS

Consider a specific new product development project that was either completed recently or is near completion to answer the following questions.

1. **Please describe the type of product that was being developed:**

   ____

   ____

2. **Please indicate the category that best describes the product at the time of development:**

   ☐ New-to-world product ☐ Major revision to an existing product
   ☐ Product line new to the firm ☐ Incremental change to an existing product
   ☐ Addition to the firm's existing product line

3. **What was the approximate duration of the new product development project (in years)?** __________

4. **Please indicate when the new product development project was completed:**

   ☐ Not yet completed ☐ Between 2 and 5 years ago
   ☐ Within the last 2 years ☐ More than 5 years ago

5. **Please check all the functional areas within your organization and external organizations that were represented on the project team:**

   ☐ Marketing and sales ☐ Purchasing ☐ Manufacturing
   ☐ Research and development ☐ Engineering/Design ☐ Customer Support
   ☐ Suppliers ☐ Customers ☐ Partner firms
   ☐ Other (please specify) ____________________

6. **If the project team consisted of sub-teams in different locations, for each please specify the team size, location (i.e. country and city) and affiliation (i.e. partner, supplier, customer, division, or parent/subsidiary company).**

   ____

   ____

   ____

7. **Please indicate the total number of project team members from within your company:** ________

8. **Please indicate the total number of project team members external to your company:** ________

9. **What was the approximate total effort (internal and external) invested by the project team in terms of person-years to complete the project?** __________

10. **Please indicate where team members were located:**

    ☐ In one building/office ☐ In several cities, but one country
    ☐ In several locations, but one city ☐ In more than one country

11. Please indicate your level of agreement with each of the statements describing the project and its context:

a. Team Stability and Resources	**Strongly disagree**				**Strongly agree**	**Unable to rate**
Most of the project managers and leaders who started this project remained on it from start to completion.	1	2	3	4	5	☐
Most of the team members who were on the team remained on it from start to completion.	1	2	3	4	5	☐
Most of the team members were assigned to this project on a full-time basis.	1	2	3	4	5	☐
Most of the team members worked together on previous development projects.	1	2	3	4	5	☐
The project team members possessed all the necessary technical skills and experience to complete the project successfully.	1	2	3	4	5	☐
The project team managers/leaders possessed all the necessary managerial skills and experience to complete the project successfully.	1	2	3	4	5	☐
The project received sufficient financial support (i.e. the budget was adequate).	1	2	3	4	5	☐
The project received strong senior management support.	1	2	3	4	5	☐

b. Technological and Market Uncertainty	**Strongly disagree**				**Strongly agree**	**Unable to rate**
The technology in the industry had been changing rapidly during the execution of the project.	1	2	3	4	5	☐
Customers' preferences/requirements changed quite a bit during the execution of the project.	1	2	3	4	5	☐
The number of product parts in this product is very high.	1	2	3	4	5	☐
Product parts in this product are highly interdependent.	1	2	3	4	5	☐
The technologies used in this product were new (unfamiliar) to the project team members.	1	2	3	4	5	☐

c. Support for Learning and Integration	**Strongly disagree**				**Strongly agree**	**Unable to rate**
Your organization's policies and culture are supportive of knowledge acquisition, sharing and application.	1	2	3	4	5	☐
Senior management in your organization is supportive of knowledge management and learning initiatives.	1	2	3	4	5	☐
The immediate project team leadership was actively supportive of knowledge acquisition, sharing, and application among team members.	1	2	3	4	5	☐
Formal mechanisms to promote interdepartmental integration exist in your organization.	1	2	3	4	5	☐
Senior management in your organization is promoting interdepartmental integration.	1	2	3	4	5	☐
The immediate project team leadership was actively supportive of building high levels of project team integration.	1	2	3	4	5	☐

PART II: INTERNET-BASED TECHNOLOGY USE

12. Please indicate the extent to which Internet-based technologies have been applied by the project team members to support the following activities:

a. Data and Information Management	**None or to a little extent**			**To a very great extent**		**Unable to rate**
Access and request product data and other information	1	2	3	4	5	☐
Collect, store, categorize, and retrieve data and other information	1	2	3	4	5	☐
Exchange messages with one another	1	2	3	4	5	☐
Send, forward, receive, and reply to messages from other team members	1	2	3	4	5	☐
Exchange files or documents with one another	1	2	3	4	5	☐

b. Collaborative Team Work	**None or to a little extent**			**To a very great extent**		**Unable to rate**
Conduct virtual meetings of distributed team members	1	2	3	4	5	☐
Provide virtual work environment for sharing resources and information	1	2	3	4	5	☐
Provide virtual work environment for performing activities jointly and simultaneously	1	2	3	4	5	☐
Provide real-time or near real-time communication among team members	1	2	3	4	5	☐

c. External Partner/Supplier/Customer Involvement	**None or to a little extent**			**To a very great extent**		**Unable to rate**
Communicate and exchange ideas with external partners/suppliers/customers	1	2	3	4	5	☐
Obtain inputs and feedback from partners/suppliers/customers	1	2	3	4	5	☐
Provide data sharing with external partners/suppliers/customers	1	2	3	4	5	☐
Enable participation of external partners/suppliers/customers in virtual work environment	1	2	3	4	5	☐

d. Project Management	**None or to a little extent**			**To a very great extent**		**Unable to rate**
Coordinate activities performed by team members	1	2	3	4	5	☐
Support project go-kill decision making	1	2	3	4	5	☐
Monitor project schedule and budget	1	2	3	4	5	☐
Conduct performance monitoring and assessment	1	2	3	4	5	☐
Perform risk assessment activities	1	2	3	4	5	☐

13. Please indicate the extent of the use of the following technologies during the execution of the project:

	Not used or used to a little extent				Used to a very great extent	Unable to rate
Electronic mail	1	2	3	4	5	☐
Instant messaging or chat rooms	1	2	3	4	5	☐
Teleconferencing	1	2	3	4	5	☐
Videoconferencing	1	2	3	4	5	☐
Electronic message boards or discussion boards	1	2	3	4	5	☐
Internet-based document management systems	1	2	3	4	5	☐
Internet-based project workspace and file sharing systems	1	2	3	4	5	☐
Internet-based calendars and meeting schedulers	1	2	3	4	5	☐
Internet-based workflow management systems	1	2	3	4	5	☐
Internet-based project management systems	1	2	3	4	5	☐
Internet-based simulation, design or modeling tools	1	2	3	4	5	☐
Integrated collaboration products such as Lotus Notes/Domino	1	2	3	4	5	☐
Internet-based software packages created for the purpose of supporting NPD, such as Metaphase or Windchill	1	2	3	4	5	☐
Other (please specify) ____________________	1	2	3	4	5	☐
Other (please specify) ____________________	1	2	3	4	5	☐

14. Please indicate your level of agreement with each of the statements describing the role of Internet-based technologies in your project:

	Strongly disagree				Strongly agree	Unable to rate
The extent of use of Internet-based technologies on this project was appropriate to achieve the project goals.	1	2	3	4	5	☐
This NPD project would not be feasible without the use of Internet-based technologies.	1	2	3	4	5	☐

15. Please indicate the overall impact of Internet-based technologies on your project performance:

	Strongly negative		No impact		Strongly positive	Unable to rate
The impact of the Internet-based technologies used on this project on the project performance was:	1	2	3	4	5	☐

PART III: PROJECT TEAM WORK

16. Please indicate your level of agreement with each of the following statements:

a. Communication Quality	**Strongly disagree**				**Strongly agree**	**Unable to rate**
Communication among project team members was timely.	1	2	3	4	5	☐
Communication among project team members was reliable.	1	2	3	4	5	☐
Communication among project team members was open.	1	2	3	4	5	☐
Communication among project team members was accurate.	1	2	3	4	5	☐
Communication among project team members was effective.	1	2	3	4	5	☐

b. Knowledge Acquisition	**Strongly disagree**				**Strongly agree**	**Unable to rate**
The project team displayed a high level of competence in acquiring the information needed to develop the product.	1	2	3	4	5	☐
The project team acquired the information needed to develop the product from a variety of sources.	1	2	3	4	5	☐
The project team gathered sufficient relevant internal and external information regarding customers, markets, technologies, and competitors during the project.	1	2	3	4	5	☐
The project team organized and stored the information generated during the process in a meaningful way.	1	2	3	4	5	☐

c. Knowledge Sharing	**Strongly disagree**				**Strongly agree**	**Unable to rate**
The project team was successful at distributing information needed for task completion among the team members.	1	2	3	4	5	☐
Project team members were well aware of where specialized knowledge is located and needed in the project.	1	2	3	4	5	☐
Project team members had good insight of what everybody else involved with this project was doing.	1	2	3	4	5	☐
Project team members developed a similar understanding of the role the acquired information would play in developing the product.	1	2	3	4	5	☐
Project team members openly shared their ideas with each other.	1	2	3	4	5	☐

d. Knowledge Application	**Strongly disagree**				**Strongly agree**	**Unable to rate**
During the project, the product development process improved.	1	2	3	4	5	☐
The project team had the ability to incorporate lessons learned during the project into the final product.	1	2	3	4	5	☐
The project team had the ability to translate customer needs into product design specifications.	1	2	3	4	5	☐
The project team was able to effectively respond to changes in customer needs.	1	2	3	4	5	☐
The project team was able to effectively respond to changes in technological environment.	1	2	3	4	5	☐
The project team was very good at joint problem solving.	1	2	3	4	5	☐

e. **Team Integration**	**Strongly disagree**				**Strongly agree**	**Unable to rate**
Activities performed by different project team members were well coordinated.	1	2	3	4	5	☐
The resources were allocated within the team effectively.	1	2	3	4	5	☐
Project team members were assigned to tasks matching their knowledge and skills.	1	2	3	4	5	☐
Project team members had common vision and goals.	1	2	3	4	5	☐
Project team members shared resources to complete tasks.	1	2	3	4	5	☐
Project team members achieved goals collectively.	1	2	3	4	5	☐
Project team members worked together as a team.	1	2	3	4	5	☐
Project team members sought integrative solutions.	1	2	3	4	5	☐
Project team members recognized each other's talents and expertise.	1	2	3	4	5	☐
Project team members were likely to defend each other from criticism by outsiders.	1	2	3	4	5	☐
Project team members helped each other to more effectively perform their tasks.	1	2	3	4	5	☐
Project team members got along well with each other.	1	2	3	4	5	☐
Project team members perceived their problems as mutual problems.	1	2	3	4	5	☐

PART IV: PRODUCT DEVELOPMENT PERFORMANCE

17. Please rate your product quality as compared to:

	Significantly Inferior		**About the same**		**Significantly superior**	**Unable to rate**
Quality goals at the start of the project:	1	2	3	4	5	☐
Quality of similar past products:	1	2	3	4	5	☐
Quality of similar competitor products:	1	2	3	4	5	☐

18. Please rate the time taken to develop and launch this product as compared to:

	Much longer		**About the same**		**Much shorter**	**Unable to rate**
Time expected at the start of the project:	1	2	3	4	5	☐
Time taken to develop and launch similar products in your organization in the past:	1	2	3	4	5	☐
Time taken to develop and launch similar products by your nearest competitors:	1	2	3	4	5	☐

19. Please rate the total project cost as compared to:

	Much higher		**About the same**		**Much lower**	**Unable to rate**
The budget goal:	1	2	3	4	5	☐
The total cost of similar past projects in your organization:	1	2	3	4	5	☐
The total cost of similar projects executed by your nearest competitors:	1	2	3	4	5	☐

PART V: DEMOGRAPHIC DATA

20. Please indicate the approximate number of employees at your firm:

☐ 25-49 ☐ 50-99 ☐ 100-499 ☐ 500-999 ☐ 1000-2000 ☐ more than 2000

21. Please indicate the country your company's head office is located in:

☐ Canada ☐ United States of America ☐ Other (please specify) ____________________

PART VI: COMMENTS

Please make additional comments, if any, regarding the use of Internet-based technologies during your project (e.g. difficulties faced, benefits obtained).

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

If you would like to provide additional information, please use extra sheets of paper.

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

Appendix E Request for research findings form

REQUEST FOR RESEARCH FINDINGS

If you would like to receive a summary of the research findings from this study, please either:

1. Provide your contact information: Name: ____________________________

Address: ____________________________

____

or e-mail address: ____________________________

2. Attach a business card to the questionnaire

3. Write an email requesting the summary at dderegow@connect.carleton.ca

4. Phone 905-637-0097 to request the summary (if no answer, leave a message)

Any personal information you provide will be kept strictly confidential.

Appendix F Measurement items: codes and definitions

Items measuring Internet-based technology use:

IBT_A1: Please indicate the extent to which Internet-based technologies have been applied by the project team members to access and request product data and other information.

IBT_A2: Please indicate the extent to which Internet-based technologies have been applied by the project team members to collect, store, categorize, and retrieve data and other information.

IBT_A3: Please indicate the extent to which Internet-based technologies have been applied by the project team members to exchange messages with one another.

IBT_A4: Please indicate the extent to which Internet-based technologies have been applied by the project team members to send, forward, receive, and reply to messages from other team members.

IBT_A5: Please indicate the extent to which Internet-based technologies have been applied by the project team members to exchange files or documents with one another.

IBT_B1: Please indicate the extent to which Internet-based technologies have been applied by the project team members to conduct virtual meetings of distributed team members.

IBT_B2: Please indicate the extent to which Internet-based technologies have been applied by the project team members to provide virtual work environment for sharing resources and information.

IBT_B3: Please indicate the extent to which Internet-based technologies have been applied by the project team members to provide virtual work environment for performing activities jointly and simultaneously.

IBT_B4: Please indicate the extent to which Internet-based technologies have been applied by the project team members to provide real-time or near real-time communication among team members.

IBT_C1: Please indicate the extent to which Internet-based technologies have been applied by the project team members to communicate and exchange ideas with external partners/suppliers/customers.

IBT_C2: Please indicate the extent to which Internet-based technologies have been applied by the project team members to obtain inputs and feedback from partners/suppliers/customers.

IBT_C3: Please indicate the extent to which Internet-based technologies have been applied by the project team members to provide data sharing with external partners/suppliers/customers.

IBT_C4: Please indicate the extent to which Internet-based technologies have been applied by the project team members to enable participation of external partners/suppliers/customers in virtual work environment.

IBT_D1: Please indicate the extent to which Internet-based technologies have been applied by the project team members to coordinate activities performed by team members.

IBT_D2: Please indicate the extent to which Internet-based technologies have been applied by the project team members to support project go-kill decision making.

IBT_D3: Please indicate the extent to which Internet-based technologies have been applied by the project team members to monitor project schedule and budget.

IBT_D4: Please indicate the extent to which Internet-based technologies have been applied by the project team members to conduct performance monitoring and assessment.

IBT_D5: Please indicate the extent to which Internet-based technologies have been applied by the project team members to perform risk assessment activities.

Items measuring communication quality:

CQ1: Communication among project team members was timely.

CQ2: Communication among project team members was reliable.

CQ3: Communication among project team members was open.

CQ4: Communication among project team members was accurate.

CQ5: Communication among project team members was effective.

Items measuring effectiveness of team learning:

KAcq1: The project team displayed a high level of competence in acquiring the information needed to develop the product.

KAcq2: The project team acquired the information needed to develop the product from a variety of sources.

KAcq3: The project team gathered sufficient relevant internal and external information regarding customers, markets, technologies, and competitors during the project.

KAcq4: The project team organized and stored the information generated during the process in a meaningful way.

KS1: The project team was successful at distributing information needed for task completion among the team members.

KS2: Project team members were well aware of where specialized knowledge is located and needed in the project.

KS3: Project team members had good insight of what everybody else involved with this project was doing.

KS4: Project team members developed a similar understanding of the role the acquired information would play in developing the product.

KS5: Project team members openly shared their ideas with each other.

KApp1: During the project, the product development process improved.

KApp2: The project team had the ability to incorporate lessons learned during the project into the final product.

KApp3: The project team had the ability to translate customer needs into product design specifications.

KApp4: The project team was able to effectively respond to changes in customer needs.

KApp5: The project team was able to effectively respond to changes in technological environment.

KApp6: The project team was very good at joint problem solving.

Items measuring team integration:

IFun1: Activities performed by different project team members were well coordinated.

IFun2: The resources were allocated within the team effectively.

IFun3: Project team members were assigned to tasks matching their knowledge and skills.

INorm1: Project team members had common vision and goals.

INorm2: Project team members shared resources to complete tasks.

INorm3: Project team members achieved goals collectively.

INorm4: Project team members worked together as a team.

INorm5: Project team members sought integrative solutions.

ISoc1: Project team members recognized each other's talents and expertise.

ISoc2: Project team members were likely to defend each other from criticism by outsiders.

ISoc3: Project team members helped each other to more effectively perform their tasks.

ISoc4: Project team members got along well with each other.

ISoc5: Project team members perceived their problems as mutual problems.

Items measuring NPD performance:

Quality1: Please rate your product quality as compared to quality goals at the start of the project.

Quality2: Please rate your product quality as compared to quality of similar past products in your organization.

Quality3: Please rate your product quality as compared to quality of similar competitor products.

Time1: Please rate the time taken to develop and launch this product as compared to time expected at the start of the project.

Time2: Please rate the time taken to develop and launch this product as compared to time taken to develop and launch similar products in your organization in the past.

Time3: Please rate the time taken to develop and launch this product as compared to time taken to develop and launch similar products by your nearest competitors.

Cost1: Please rate the total project cost as compared to the budget goal.

Cost2: Please rate the total project cost as compared to the total cost of similar past projects in your organization.

Cost3: Please rate the total project cost as compared to the total cost of similar projects executed by your nearest competitors.