

# **THE EFFECTS OF COMMUNICATION AND PROBLEM-SOLVING PATTERN ON COLLABORATIVE PRODUCT DEVELOPMENT PERFORMANCE**

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PROBLEM-SOLVING PATTERN ON COLLABORATIVE  
PRODUCT DEVELOPMENT PERFORMANCE**

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*To my beloved parents,  
and my beloved brother,  
for their love and patience.*

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## Summary

The need for supplier involvement in new product development process is becoming more intensive due to the increasing technology advances, product and technology complexity and the fast growth of international trade in today's competitive markets. However, this strategy of involving suppliers in NPD inevitably affects the product development projects performance. Brown and Eisenhardt's review on the previous studies reveals that though different factors and relations such as problem solving, communication and innovation have been studied, the interactions among these factors are still not well understood (Brown and Eisenhardt, 1995). Takeishi (2001) investigated automaker's "internal capabilities", "external coordination", and their combined effect on *component design quality* as one of the main development performances. However, there are still some relationships among the buyer and its supplier which have not been examined clearly. Consequently, this study concentrates on the three important factors which affect inter-firm product development process. These factors are:

1. Buyer-supplier communication,
2. Joint problem solving,
3. The buyer's degree of technical knowledge about the development project.

Specifically, we investigate how these factors influence product development project performance in terms of product quality and development time. We examine the moderating effect of buyer's technical knowledge about the development project, by level

of supplier responsibility in the process, and by the level of product complexity on these relationships.

Based on the replies of 59 companies in Singapore, we found that, (i) intensive routine communication and problem-solving interactions in buyer-supplier relationship improve product quality in the CPD project, (ii) buyer's technical knowledge about the development project has a moderating effect on the impact of intensive problem-solving interactions on development lead-time, (iii) the level of supplier responsibility in the project moderates the effects of intensive routine problem-solving interactions on product quality, (iv) product modularity has a moderating effect on the relationship between intensive problem-solving interactions and product quality.

The research results reveal that routine communication interactions intensity can improve the product quality in the collaborative product development projects but it may increase development lead-time. Practitioners need to manage their routine communication with the supplier in such a way that it does not delay the project and yet helps to improve the product quality. Also, buyers are suggested to manage their mutual problem-solving interactions based on their competencies when supplier is significantly involved in the product development process especially in case of grey and black box development. It may be even more effective to define the product requirements and responsibilities of each side clearly upfront when the product is modular in the collaborative product development.

## Abbreviations

<b>CPD</b>	Collaborative Product Development
<b>EDB</b>	Economic Development Board
<b>NPD</b>	New Product Development
<b>PDMA</b>	Product Development and Management Association
<b>SI</b>	Supplier Involvement
<b>SIC</b>	Standard Industrial Classification
<b>VIF</b>	Variance Inflation Factor

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# Chapter 1 Introduction

## 1.1 Research Background

New product development (NPD) consists of all processes from “concept generation, product and marketing plan creation and evaluation, and commercialization of a new product” (Kahn et al., 2005, p.450). Previously, many new product development activities were completed among intra-firm development teams. Since business environment faces higher complexity and more intensive competition, companies try to outsource some or the whole product development activities to other companies. They also collaborate with their suppliers in order to increase their competitiveness in the market. Many scholars have argued that buyers can benefit from integrating suppliers in the development process to improve product time-to-market, product quality, development cost, and product or process innovation (Birou and Fawcett, 1994; Handfield et al., 1999; Wynstra et al., 2000; Hoegl and Wagner, 2005). In this study we explore the collaborative product development (CPD) process as the joint action of buyer and supplier team members on a mutual task. CPD process aims at satisfying customer requirements, taking advantage of market opportunities especially in the stages that the firm lacks required knowledge and expertise, and responding to fast technological changes while trying to reduce the cost and risk of development process and reduce development time (Litter et al., 1995; Petersen et al., 2005). However, a key challenge faced by the collaborative new product development projects is how to acquire knowledge and manage sources of uncertainty in order to reduce the risk of failure of either the process or the resulting product (Cooper, 2003).

## **1.2 Research Objectives**

Technology advances, product and technology complexity and the fast growth of international trade intensify the need for supplier involvement in NPD (New Product Development) (Dowlatshahi, 1997; Ledwith, 2005). However, managing supplier involvement in product development has known to be quite difficult (Birou and Fawcett, 1994; Van der Valk and Wynstra, 2005). There are only a few studies presenting an integrative model of collaborative product development process. The most notable work is Takeishi's (2002), who investigated how the manufacturer's knowledge, joint problem-solving pattern and communication affect design quality. However, he did not study the interaction and effect of these factors on the collaborative product development performance. This study tries to fill this research gap by investigating buyer-supplier information sharing in the CPD process in terms of routine communication intensity, joint problem-solving interactions intensity and the timing of the application of joint problem-solving techniques in the process. Thus this research contributes to understanding the possible factors which may influence the CPD project performance. The results of this study may help managers decide what factors they need to consider in order to manage buyer-supplier information sharing during the process.

## **1.3 Thesis Structure**

This thesis consists of six chapters to describe buyer-supplier information sharing interactions in the collaborative product development process.

The current chapter is chapter 1 which shows a summary of the whole chapters and the outline of the thesis.

## Chapter 1 Introduction

Chapter 2 covers the past research on product development process, collaborative product development (CPD) process, supplier involvement in the CPD process, information sharing in the CPD process, and different factors which affect the CPD project performance. Reviewing previous studies, we propose a research gap in this field to be investigated in this study.

Chapter 3 is the theory and hypotheses chapter. In this chapter, we developed eleven hypotheses based on the literature review. These hypotheses introduce our proposed framework to investigate the factors affecting buyer-supplier information sharing interactions in the CPD process.

Chapter 4 describes the research methodology to examine our proposed hypotheses in this study. The structure of the questionnaire, measures for dependent and independent variables, and the required steps for survey implementation have been explained in detail in this chapter. Also, the constructs developed for the framework are evaluated to be reliable and valid for the study in this study.

In chapter 5, the collected data is analyzed to examine the hypotheses in the framework to investigate if the propositions are supported by data or not. All the relationships in the framework are evaluated by statistical tools.

Chapter 6 presents the results of the survey and their interpretation regarding all the arguments we mentioned in this study. The results are explored and their implications are

## Chapter 1 Introduction

discussed in this section. Also, limitation and further research opportunities are proposed for future improvement in this field of study.

# Chapter 2 Literature Review

## 2.1 Introduction

Traditionally, buyer-supplier relationships were mostly adversarial and arms-length transactions (Morrissey and Pittaway, 2003). Nowadays, this relationship is transforming towards a more collaborative nature. This change stems from the expanding belief that suppliers are essential sources to gain competitive advantage in global markets because of their expertise, knowledge and their ability to share risks.

## 2.2 Product Development Process

New product development process is the “lifeblood” which sustains the continuing survival of an organization (Barclay & Benson, 1990) since it is a potential source of competitive advantage for many companies (Clark and Fujimoto, 1991; Brown and Eisenhardt, 1995). In the current competitive markets, companies need to consider product development significantly in order to develop or keep themselves in a competitive position in the business arena (Cooper and Kleinschmidt, 1987; Schoonhoven et al., 1990; Brown and Eisenhardt, 1995; Smith and Reinetsen, 1998; Van der Valk and Wynstra, 2005). Moreover, new product development provides the opportunity for companies to create new emerging markets, new customers, and new capabilities within the firms. In addition, NPD helps companies leverage their existing assets and competencies to increase their competitiveness through facilitating relationships with other organizations (Wheelwright and Clark, 1992).

## Chapter 2 Literature Review

Product development is the overall process of following the strategies of an organization, generating concepts and ideas, creating product and marketing plan and carrying out evaluation, and commercializing new product. More specifically, product development process is a set of tasks and steps which describe the normal means by which a company converts initial ideas into commercial products or services (Kahn, 2005).

Cooper (1994, p.3) describes NPD as “a formal blueprint, roadmap, and template or thought process for driving a new product project from the idea stage to market launch and beyond”. NPD includes all activities which are required in order to conceive, design, produce, and deliver a product to market. It is also known as a specific type of innovation (Sheramata, 2000). Brown and Eisenhardt (1995) categorized NPD previous studies into three main streams: “rational plan”, “communication web”, and “disciplined problem solving”. They claim that although all these streams depict how different players, structures and processes affect product development performance, each of the streams concentrates on particular aspects of product development process. While the *rational plan* research stream focuses mostly on “determinants of financial performance” of product development process while the *communication web* considers how internal and external communication may affect NPD performance. The *disciplined problem-solving* stream concentrates on a development team, the suppliers, and leaders in NPD process.

Table 2.1 illustrates the comparison of the three major research streams introduced by Brown and Eisenhardt (1995).

**Table 2.1- Comparison of Three Research Streams in NPD Process (Brown and Eisenhardt, 1995)**

<b>Concepts</b>	<b>Rational Plan</b>	<b>Communication Web</b>	<b>Disciplined Problem Solving</b>
<b>Key idea</b>	Success via superior product, alternative market, rational organization	Success via internal and external communication	Success via problem solving with discipline
<b>Theory</b>	Mostly atheoretical	Information and resource dependent	Information including problem solving
<b>Methods</b>	Bivariate analysis; single informant; many independent variables	Deductive and inductive; multivariate; multiple informants	Progression from inductive to deductive; multiple informant; single industry, global studies
<b>Product</b>	Product advantage – cost, quality, uniqueness, fit with core components	–	Product integrity – Product vision that fits with customers and firm
<b>Market</b>	Size, growth, competition	–	–
<b>Senior Management</b>	Support	–	Subtle Control
<b>Project team</b>	X-functional, skilled	–	X-function
<b>Communication</b>	High cross-functional	High internal, high external – various types and means	High internal
<b>Organization of work</b>	Planned and “effective” execution	–	Overlapped phases, testing, iteration, and planning
<b>Project leaders</b>	–	Politician and small group manager	Heavyweight leader
<b>Customers</b>	Early involvement	–	–
<b>Suppliers</b>	Early involvement	–	High involvement
<b>Performance (dependent variable)</b>	Functional success (profits, sales, market share)	Perceptual Success (team and management ratings)	Operational success (speed, productivity)

### **2.3 Collaborative Product Development**

Traditionally many new product development activities were completed by geographically co-located development teams. Co-location required all critical team members (engineering, marketing, manufacturing, and perhaps finance, procurement, regulatory, and others) to be physically close to each other to overhear mutual conversations. However, increasing globalization trend leads development teams to get more dispersed rather than being co-located (Kahn, 2005).

Nowadays, new product development processes are increasingly becoming “disintegrated” since outsourcing and partnership grow in implementation of both production and development processes (Minderhoud and Fraser, 2005). Therefore, new product development process, now, is “a chain with many players” (Minderhoud and Fraser, 2005). Likewise, Kahn (2005, p.162) defines distributed product development process as “the separation and optimization of activities performed during a single product development process (i.e., product identification, development, launch), across multiple geographical locations. These locations may either be within a single corporate entity, within subsidiaries, or involve the use of third parties.” Croom (2001) categorizes dyadic capabilities on the basis of product technical dimensions, manufacturing processes and interactions among parties.

Distributed product development trend is growing as a result of specialization, globalization and new enablers such as information technology systems which facilitate interactions among different players in the process. The benefits of distributed product

## Chapter 2 Literature Review

development depend on both the characteristics of the product, the capabilities of the organization and the characteristics of the industry. Kahn (2005) mentions the main advantages of distributed product development as follows:

- Lower development costs
- Labour costs
- Productivity gains
- Focused R&D investments
- Access to greater capabilities and specialized skills
- Shorter development times (shorter life cycle)
- Better risk management
- Improved product targeting

Collaborative product development intensifies competition in many industries forcing manufacturing firms to develop new, higher quality products at an increasingly rapid pace. Overlapping product development activities is also an important component of concurrent product development which helps firms develop products faster.

Many scholars studied product development performance criteria in terms of development lead time, product quality, development cost, and innovation (Schoonhoven et al., 1990; Gupta and Souder, 1998; Smith and Reinersten, 1998; Primo and Amundson, 2002).

## **2.4 Supplier Involvement in the Collaborative Product Development Process**

In many industries, competitive advantage is rapidly shifting to the management of suppliers, which can account for as much as 60 to 80 percent of manufacturing costs (Verona, 1999). Suppliers can exert a strong influence on throughput time and work-in-process inventory, and play an often critical role in new product development. Companies that integrate their supplier base effectively with their internal engineering, manufacturing, and purchasing operations benefit from reduced costs, shorter lead times, lower development risks, and compressed development cycles (Asmus and Griffin, 1993).

Moreover, many researchers emphasize that innovation, as a critical strategic process, is the core of product development (Penrose, 1959; Hamel and Prahalad, 1994). Suppliers have been recognized as a source of innovation for NPD process (Hakansson, 1987; Bonaccorsi and Lipparini, 1994; Nishiguchi and Ikeda, 1996; Van der Valk and Wynstra., 2005). Therefore, suppliers are involved into the firm's production and design process while they significantly become more responsible for the design of the whole systems or subassemblies systematically (Bonaccorsi and Lipparini, 1994; Womack et al., 1990).

Earlier and more extensive supplier involvement in product development is one of the most efficient ways to improve product development performance criteria such as productivity, speed and product quality (Clark, 1989; Gupta and Souder, 1998; Ragatz et al., 2002; Primo and Amundson, 2002; Van der Valk and Wynstra., 2005). Also, the involvement of suppliers in NPD helps companies gain shorter project times (Clark, 1989; Clark and Fujimoto, 1991), better product quality and lower project costs (McGinnis and

Vallopra, 1998; Ragatz et al., 1997). However, some scholars have argued that suppliers have little practical influence on the overall technical success of the NPD projects (Hartley et al., 1997). It is also claimed that supplier involvement in NPD can even have a negative impact on project development time if they delay their activities (King and Penleskey, 1992).

The strategic role of suppliers has been changed extensively as a result of more supplier involvement in product development and product innovation (Burt and Soukup, 1985; Helper, 1991; Clark and Fujimoto, 1991; Hakansson and Eriksson, 1993; Lamming, 1993; Hines, 1994). In this scenario suppliers can play more significant roles in the product design and development process (Croom S.R., 2001). Therefore, management of supplier involvement in product development is a critical strategic process.

### **2.5 Importance of Supplier Involvement in the Collaborative Product Development Process**

Product development process consists of a set of activities including a lot of functions, both inside and outside the firm. As technological complexity and product performance grow fast, it is important to manage relationships with suppliers to approach firm's success (Bonaccorsi A. and Lipparini A., 1994). Effective integration of suppliers into product development process can lead to some benefits such as lower project cost, enhanced quality of purchased materials, reduced product development time, and improved access to and application of technology (Ragatz et al., 1997). Buyer-supplier collaboration can also improve the competitive position and minimise risk, but it does not

## Chapter 2 Literature Review

necessarily reduce development time (Hauschildt and Kirchmann, 2001). Strong formal ties between R&D networks and suppliers can play an important role in improving CPD team members' technical skills and expertise. On the other hand, the effort needed for integrating suppliers into NPD process can influence development process negatively. This is more significant when the differentiation among NPD participants increases. In this case, suppliers' integration toward achievement of mutual goals is more challenging (Susman and Ray, 1999). According to Clark (1989), additional coordination time is needed when relationships with suppliers are complicated to manage in the collaborative process. Primo and Amundson (2002) also claim that lack of priority in suppliers cooperation in NPD process affect product development outcomes negatively.

The influence of supplier involvement in NPD depends on managing the buyer-supplier interactions and relationship. In fact, buyer-supplier relationship management is a way to ensure effective levels of integration and performance through NPD process (Birou and Fawcett, 1994). Analysis of supplier involvement indicates that since interaction is a "dyadic process", effective collaborative performance depends on the management of relationships by both the supplier and the customer. Therefore, understanding the dimensions and development of dyadic capabilities helps companies manage their supplier interactions and relationships to enhance collaborative development performance (Croom, S.R., 2001).

## **2.6 Information Sharing in the Collaborative Product Development Process**

Linder et al., (2001) have explained outsourcing relationships over two ways of information sharing: conventional and collaborative. Sosa et al. (2002) also studied different types of communication among technical members of NPD team. They found that though the most parts of technical communication among interacting team members is likely to involve coordinative and innovative information, these are not the only types of communication. Team members may also participate in technical communication for inspiration and general knowledge and not directly related to specific development tasks (Morelli et al., 1995). Team members can also communicate for “creative inspiration”, “managerial affirmation”, and to “keep up-to-date with the latest developments in their disciplines” (Sosa et al., 2002).

Some authors (Allen and Hauptman, (1989); De Mayer, (1991); Morelli, (1995); Hauptman, (1996); Sosa et al., (2002)) have suggested the following categorization for technical communication:

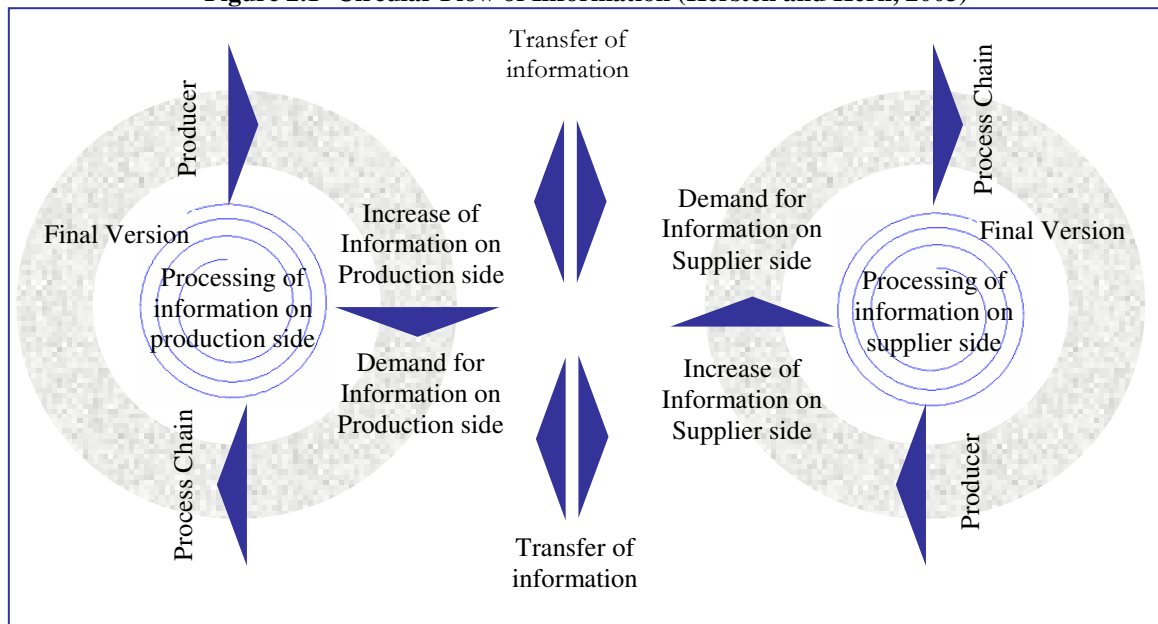
- **Coordinative:** to decrease technical information deficiency.
- **Innovative:** to decrease technical ambiguity.
- **Affirmative:** to enhance technical motivation.

### **2.6.1 Factors affecting Information Sharing among Product Development Team and Suppliers**

The efficiency of NPD processes across company borders is determined by the quality of inter-organizational cooperation. The design of information flows between the partners

indicates a decisive key factor. Well designed information flows are characterized by whether the information the partners need, reaches the right addressee at the right time. In addition, the information quality and quantity has to be fit to the specific requirements of the partners. The company's specific processes and the processing state of the information determine which information is required at what time by which partner. Another decisive factor is the cooperating companies' knowledge of their own processes. Also it is necessary for them to know the processes and therefore information needs of their partners. Therefore, "target-oriented transfer of information" does not primarily result from a request but also when one company detects that another partner has to be informed because of the progress of the process (Fig. 2.1) (Kersten and Kern, 2003).

**Figure 2.1- Circular Flow of Information (Kersten and Kern, 2003)**



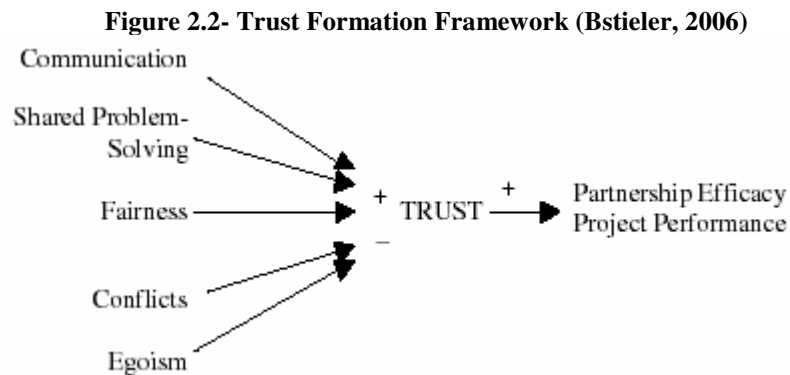
## **2.7 Collaborative Product Development Management**

Supplier integration in NPD includes some advantages which have long-term positive influence on NPD effectiveness and efficiency. For instance, it provides firms the opportunity to have better access to suppliers' knowledge and expertise while developing clearer mutual understanding of joint development projects objectives (Ragatz et al., 1997). Also, in a study of collaboration in the UK automobile industry, Croom (2001) found that suppliers' capability in terms of familiarity, empathy and adaptability to customer were dominant criteria which show the importance of interaction in NPD process. This study suggests that during supplier selection process, it is necessary to consider suppliers' strategic capabilities (including management of their customer interactions) rather than focusing only on component/system-related criteria.

In addition, increased attention to relational competencies has significant impact on collaborative product development performance. Relational competencies are those pertaining to communication, interaction, problem resolution, and relationship development (Croom and Batchelor, 1997; Croom, 2001). Company's organizational structures, specific cultures, cooperation strategies, processes and information technology infrastructure as well as competencies influence the success of the collaboration (Kersten and Kern, 2003)

Bstieler (2006) argues that communication, shared problem-solving and fairness positively affect trust which results in improving partnership efficacy in terms of project performance (Fig. 2.2). He also studies the negative impact of conflicts and egoism on

product development partnership outcomes. In this study, he asserts that trust helps social interactions continue on a simple and confident basis. Individuals who trust each other are more likely to share ideas and relevant information or to clarify problems.



The progress of supplier involvement is influenced by different degrees of interaction and communication between manufacturer and suppliers. It is often focused on the technical issues which are related to design concerns. However, it is also frequently involving discussion of relational issues relating to the degree of “on site representation”, “the flow of information through the supplier organization”, and “demonstration of commitment through dedicated project management teams” (Croom, 2001, p.34).

There are different factors which affect collaborative product development performance. Various scholars suggested different frameworks to elaborate which concepts may influence buyer-supplier collaboration while they tried to study possible interactions on the CPD project performance. In an empirical study of the CPD process, Clark (1989) concluded that strong inter-firm communications and shared problem-solving may reduce required engineering working hours during the process. Wasti and Liker (1999) also

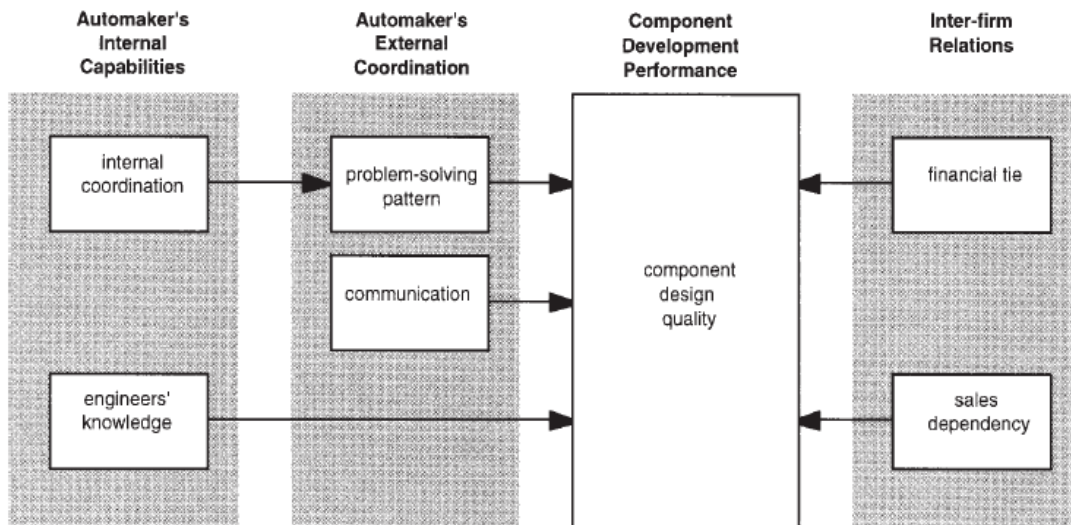
## Chapter 2 Literature Review

suggested that “design-related communication” and supplier involvement in early stages of development process improves product design. In a study on the content of inter-firm communications, Petersen et al. (2005) also claimed that buyer-supplier joint interactions to set technical objectives and project targets could improve product development team effectiveness. Moreover, in a survey on Japanese automakers, Takeishi (2001) studied the direct effects of the following factors on component design quality:

- Automaker’s internal capabilities
- Automaker’s external coordination
- Inter-firm relations

Figure 2.3 shows this framework in detail:

**Figure 2.3- Collaborative Inter-firm Relations (Takeishi, 2001)**



According to his framework, inter-firm collaboration in development process is a multi-faceted relationship. However, he did not investigate the possible interactions among his proposed constructs and how they may affect the CPD project performance.

Supplier integration into product development process is a “social process” which is affected by various “behavioural factors” (Bensaou and Venkatraman, 1995; Eisenhardt and Tabrizi, 1995; Meijer, 1998). Some scholars investigated how to improve supplier integration in NPD process from different viewpoints. Table 2.2 summarizes the most applicable theoretical perspectives to buyer-supplier relationship.

**Table 2.2- Summary of Theoretical Perspectives to Buyer-Supplier Relationship**

	<b>Theoretical Perspective</b>	<b>Investigation</b>
1	Transaction Cost Economics (TCE)	Williamson (1985), Dyer (1997), Noteboom et al.(1997), Saxton (1997)
2	Relational Theory	Dyer and Ouchi (1993), Zajac and Oslen (1993), Dyer and Singh (1998)
3	Organizational Design Theory	Granovetter (1992), Hagedoorn (1993), Combs and Ketchen (1999)
4	Network Governance	Kogut (1988), Granovetter (1992), Osborn and Hagedoorn (1997), Holm et al. (1999)

All of these perspectives advocate that the buyer-supplier integration into product development process requires “coordinating mechanisms” to succeed (Petersen et al., 2005).

### **2.7.1 Role of Communication in the CPD Process**

Collaborative development processes often suffer from “insufficient coordination of partner specific tasks” (Kersten and Kern, 2003, p.37). This results in corrective loops which causes delays in the process leading to additional costs. Therefore, information flows in organizations are essential for the quality of development processes (Sander and Brombacher, 2000). Information exchange in geographically distributed product development teams is also important due to “the highly interdependent nature of design organizations” (Sosa et al., 2002).

Communication is the exchange of information among different partners. Much of the information exchanged in collaborative product development is related to marketing, production, or technical information which includes competitive or strategic value for the process. Scholars have studied processes in the form of communication among project team members and have positively related them to speed and productivity of the development process (Brown & Eisenhardt, 1995). Moreover, when suppliers have some information about the purchasing firm’s internal processes and objectives, they can plan for future product development efforts. Consequently, they can develop the required capabilities in advance to meet these needs (Dyer and Ouchi, 1993). Thus, it is important to facilitate the exchange of essential information in order to increase the speed of NPD process (Ulrich and Eppinger, 2000).

Although communication pattern in NPD relies on “the nature of the project” and “the organizational structure” (Barczak and Wilemon, 1991; Morelli and Eppinger, 1995), it is

## Chapter 2 Literature Review

also influenced by distance (Allen, 1977; De Meyer, 1991). The barriers to technical communication as a result of distance between team members have been investigated in the literature extensively. Team interdependence and organizational bonds affect technical communication positively while geographic dispersion in terms of distance, time zones difference and cultural/language difference influence it negatively. Regarding this, investigating the impact of the following factors on information sharing among manufacturer and suppliers is noticeable (Sosa et al., 2002):

- Geographical Proximity
- Frequency of Communication
- Different Time Zones
- Different Languages
- Different Organizational Culture

Inter-firm communication has been claimed to be a way of achieving strategic alignment. The content and quality of communication are critical success factors to collaboration success (Mohr and Spekman, 1994). Morgan and Hunt (1994) emphasize on meaningful and timely information sharing to resolve conflicts, reach mutual understanding and clear expectations. Timely, accurate, open, and proactive communication improves the atmosphere of buyer-supplier relationship (Bruce et al., 1995; Dyer and Chu, 2003). Timeliness refers to the extent of promptly sharing of a piece of information to a person who requires the information for his task in the project while proactiveness is the degree a person or a team may search for a piece of information (Chong et al., 2007).

### **2.7.2 Problem-solving in the collaborative product development Process**

Problem-solving is an iterative process which is driven by trial and error effort supported by knowledge of underlying cause and effect relationships (Thomke and Fujimoto, 2000). Problem-solving strategy involves cross-functional teams in NPD process (Imai et. al., 1985). This provides development team members the opportunity to access various functional specializations to explore ambiguous problems during the process more quickly and effectively. In fact, the benefits of integrated problem solving on product development performance have been investigated extensively (Clark and Fujimoto, 1991; McDonough and Barczak, 1992; Thomke and Fujimoto, 2000). However, buyer-supplier joint problem-solving pattern involves more factors in their partnership from identifying the problem to finding the feasible solution.

Clark and Fujimoto (1991) emphasize on the importance of joint problem solving from earlier stages of NPD process in order to increase the integrity among the components of the product. Product integrity is increasingly significant in the collaborative product development process because of involving suppliers in the process. According to Takeishi (2001), integration should be considered from the earlier stages of product development.

Front loading of problem-solving activities is a strategy to let buyer-supplier engineers detect potential problems as soon as possible to reduce unnecessary design changes which may occur in the later stages.

### **2.7.3 Knowledge and Collaborative Product Development Process**

Cooperation is defined as the joint development of knowledge through interactive relationships with some specific partners, such as competitors (Hagedoorn, 1993; Chiesa and Manzini, 1996; Ingham and Mothe, 1998), customers and suppliers (Urban and Von Hippel, 1988; Hakanson and Erickson, 1993), joint ventures and alliances (Kogut, 1991) as well as universities and research institutes (Bailetti and Callahan, 1995; Santoro and Chakrabarti, 2001).

Buyer-supplier cooperation usually leads to an extensive interaction between parties in a longer time period (Pisano, 1990). This interaction can result in an intensive knowledge sharing and mutual learning between buyer and the supplier. This process results in context specific and implicit knowledge (Birkinshaw and Sheehan, 2002).

Kogut (1988) explicitly argue that collaboration could be driven by an organisational learning. He suggested that collaboration "is used for the transfer of organisationally embedded knowledge which cannot be easily blueprinted or packaged through licensing or market transactions" (Kogut, 1988). Likewise, Westney (1992) and Hamel (1991) developed similar perspectives to investigate how learning can be achieved through collaborations. So far, much research has been done on the knowledge transfer process across alliance and joint venture boundaries (e.g. Doz and Santos, 1997; Inkpen, 2000). However, "development-related knowledge" is a kind of tacit knowledge and it is difficult either to codify or to articulate during the process (Bstieler, 2006).

A critical success factor in cooperation in NPD processes is the capacity to integrate external knowledge into a company's internal knowledge and to share internal knowledge with the partner to learn. Buyer's ability to find and integrate the proper supplier that can contribute the required knowledge or competencies to the process is a crucial key for the collaborative product development success.

### **2.8 Research Gap and Research Questions**

Previous studies have shown that new products can improve a firm's market share, value, and survival likelihood (e.g., Chaney and Devinney, 1992). The critical importance of new products has been investigated extensively in recent studies. Many of the internal processes of NPD are also well studied and empirically supported. However, the elements of an effective integration of external suppliers in NPD have not been investigated thoroughly (Brown and Eisenhardt, 1995; Atuahene-Gima, 1995; Hartley et al., 1997; Ragatz et al., 2002). Moreover, research on the role of information use in new product development is not well explored yet (Song et al., 2005).

In conclusion, we are going to investigate the following research questions in this study of buyer-supplier information sharing in the CPD process:

1. How does communication and problem-solving between supplier and manufacturer affect product development performance?

## Chapter 2 Literature Review

2. How does level of supplier responsibility moderate the impact of communication and problem-solving on product development performance?
3. How does product modularity moderate the impact of problem-solving on product development performance?

# Chapter 3 Theory and Hypotheses

## 3.1 Introduction

The aim of this chapter is to analyze the concepts and theories mentioned in the literature review chapter in order to clarify the research gap and investigate some possible answers to the research question. Specifically, we investigate the effect of routine communication intensity, timing and intensity of joint problem-solving interactions on the collaborative product development performance. Furthermore, we study the moderating effects of the buyer's technical knowledge, supplier responsibility, and product complexity on some of the interactions in our proposed framework.

As mentioned in the literature review chapter "supplier" in this research refers to "the first tier supplier". Following Petersen et al. (2005, p.379), we define supplier integration as follows:

“Supplier integration into product development suggests that suppliers are providing information and directly participating in decision making processes for purchased items used in the new product or service. By “suppliers” we mean suppliers external to the business unit who have been linked into your business and/ or technical processes. This participation or involvement may occur at any point in the new product/ process development model.”

In other words, this research aims to study the relationship between buyer and its first tier supplier while investigating the impact of this relationship on product quality and development lead-time in the CPD process.

### **3.2 Communication in the CPD Process**

Organizations are information processing systems which have access to limited resources to reduce the ambiguity and uncertainty of the information they acquire (Galbraith, 1973). Similarly, product development process is a transforming system which receives a set of data as inputs (e.g., customer needs, market demands, product strategy, technology requirements, manufacturing and production constraints), analyze and refine them to a set of outputs (e.g., product specifications, product design, production plan, and product prototype) (De Meyer, 1991; Hauptman, 1996; Sosa et al, 2002). Accordingly, collaborative product development process often deals with information sharing and information processing between buyer-supplier team members. Since uncertainty and equivocality influence information processing, buyer-supplier team members always need to communicate with each other to enhance their mutual understanding during decision making procedure and project progress.

Product development process is a communication web in which information and solutions are exchanged through problem-solving cycles to decrease equivocality and uncertainty (Clark and Fujimoto, 1990; Brown and Eisenhardt, 1995; Sosa et al., 2002). Moreover, communication frequency and intensity positively affect communication objectives (e.g., coordination, satisfaction, and commitment) (Mohr and Nevin, 1990, Hoegl and Wagner,

2005). In other words, when team members communicate with each other intensively and frequently, it is more likely that the ambiguity in the message reduced through the process of information exchange. Similarly, in collaborative product development, when information about the content and situation of the mutual tasks is frequently shared, project team members are more informed and they can apply their up-to-date information in their work as well as in their problem solving patterns (Ragatz et al., 1997; Hoegl and Wagner, 2005). Thus, buyer and suppliers try to reduce information uncertainty and equivocality through mutual communication in order to enhance their collaborative relationship in order to improve the performance of the outcome product.

### **3.2.1 Routine Communication and Product Development Performance**

Buyer and supplier team members need to communicate frequently to share the required information during the development process progress. They exchange information regarding either product or project management progress to facilitate the development project process.

They need to communicate their demands, expectations, capabilities, and conditions while they have to exchange different ideas and solutions during the progress of the project. Moreover, they try to communicate with each other frequently to exchange information in order to decrease information uncertainty as much as possible (Pinto and Pinto, 1990). This kind of communication includes all the interactions to communicate general information during mutual meetings. Both parties exchange information about the pre-defined tasks and events they have negotiated before. In other words, the context and nature of the problems being analyzed in routine communication are almost clear and

predictable. In this kind of communication buyer and supplier share their current information to keep each other up-dated about the progress of the project, to review the project progress, to predict any possible further changes in product or project process, and to negotiate the required coordination (Takeishi, 2002; Van der valk and Wynstra, 2005). This type of buyer-supplier communication takes place in order to reduce information deficit in the collaborative product development process. Since the collaborative development team members often deal with “imprecise information” during the process, they frequently communicate with each other to “define problems or to reach a consensus on the solution of a problem” (Sosa et al., 2002, p.46).

According to previous studies, the content and quality of communication are the key ingredients to collaboration success (Mohr and Spekman, 1994; Bstieler, 2006). Previous research findings on new product development have articulated the significance of meaningful and timely information exchange in order to resolve disputes, reach shared understanding, align perceptions and clarify expectations (Morgan and Hunt, 1994). Similarly, collaborative product development team members need to exchange substantive information extensively to make sure that key component designs were coordinated with overall product requirements (Litter et al., 1995). Timely, accurate, open, and proactive communication helps buyer and supplier to develop mutual understanding while improving the atmosphere of their relationship. Also, it increases commitment that expected deadlines are respected (Bruce et al., 1995; Dyer and Chu, 2003).

In conclusion, routine communication deals with coordinative information in order to coordinate product development activities in collaborative projects. When information

about the content and status of the project is exchanged frequently, it is more likely that all project members get informed about the most up-to-date status of the project and apply it to their piece of work (Ragatz et al., 1997). This can lead to higher conformity to desired product specifications. Thus, buyer-supplier intensive routine communication can enhance product quality in CPD project. Also, frequent communication may result in less misunderstanding and disagreement among two players. Therefore, the number of time delays which may happen during the process due to lack of required information decreases. Communication increases the variety and amount of information that enhances the performance of product development. These arguments lead us to propose the following hypotheses:

H1: *The intensity of routine communication* between NPD team and suppliers has a positive relationship with *product quality* in product development projects with supplier involvement.

H2: *The intensity of routine communication* between NPD team and suppliers has a negative relationship with *development lead-time* in product development projects with supplier involvement.

### **3.3 Joint Problem-Solving Pattern in the CPD Process**

Collaborative product development consists of continuous information sharing and problem solving procedures. Buyer and supplier are involved in different tasks in collaborative product development process. Therefore, they need to have mutual

understanding of the situations and problems they may encounter during the process. As mentioned in the previous section, buyer and supplier exchange some common information to facilitate the progress of the project in accordance with the project plan (Wynstra et al., 2000). However, there are some situations along the process which both parties may encounter some unpredicted problems that they might not be ready to take a suitable action against. In other words, there are some unexpected problems which may influence the initial decisions defined in the project plan. This may lead to some revisions in the preliminary plan. These problems are ambiguous in nature and they need to be defined clearly in order to find proper solutions. In these situations equivocality is high since the collaborative team experience imprecise information and ambiguous ambience. Therefore, they try to define the problem, analyze the unexpected situations and reach consensus on the feasible solutions on the problem.

Some scholars studied different dimensions of joint problem solving pattern in collaborative product development while investigating their impacts on the product performance. However, most of the studies focus on the timing and stage of supplier involvement in the development process while just a few of them consider the necessity and existence of continuous flow of problem solving interactions during the process and how it may affect the product development process performance. This research studies problem solving pattern in terms of both the timing and intensity of problem solving interactions among buyer-supplier team members trying to understand how these two factors may influence the product development performance.

In order to appropriate the knowledge which resides in a partner, close involvement in decision-making processes is needed (Saxton, 1997; Bstieler, 2006). Close collaboration with a supplier can reduce the risks of designing a product or a component difficult to manufacture (Asmus and Griffin, 1993). The buyer and its supplier can try, err, and search for solutions and exchange feedback between each other during joint problem-solving process. When they experience this process continuously, they can share a mutual understanding in the process (Ring and Van de Ven, 1994). Joint problem-solving enables buyer and its supplier to coordinate functions and work on the problems to reach new solutions and new combinations of innovative ideas (Uzzi, 1997). Buyer-supplier collaboration can facilitate detecting potential downstream problems earlier when they are easier and faster to fix.

### **3.3.1 Problem-solving Interactions Intensity**

Although early involvement of joint problem solving techniques in the collaborative product development process is important, it does not assure the continuity and reliability of the mutual problem solving activity between buyer and supplier. More specifically buyer and supplier members not only need to be involved in the process from the earlier stages, but also do they need to frequently contribute their ideas in the process of resolving problems and making decisions during the development project (Vroom, 1987). Frequent exchange of solutions among both parties will decrease possible deviations from the targeted requirements in the final outcome. The third hypothesis suggests that:

H3: *The intensity of problem-solving oriented interactions* between NPD team and suppliers is negatively associated with *product quality* in product development projects with supplier involvement.

Likewise, frequent problem-solving interactions during the collaboration can help buyer and supplier detect the unpredicted problems from earlier stages. This can help to reduce the risk of time lags which may occur due to the sudden problem during the process and reduce the development lead-time. Therefore:

H4: *The intensity of problem-solving oriented interactions* between NPD team and suppliers is negatively associated with *development lead-time* in product development projects with supplier involvement.

### **3.3.2 Early Involvement of Joint Problem-solving**

Problem solving strategy in NPD process involves cross-functional development teams from the earlier stages of product development in order to reduce ambiguity and to increase product development effectiveness (Clark and Fujimoto, 1991). Takeishi (2001) also describes problem solving as a part of “external coordination” which enhances consistency among the various tasks in collaborative product development process. In fact, many studies assert that product development is “a system of interconnected problem solving cycles” which requires cross-functional coordination across different groups in development process from the early stages of development (Clark and Fujimoto, 1991). This kind of coordination enhances problem identification and mutual solution searching

procedures from the early stages of development process which avoid iterations, reduce unnecessary design changes, improve component design and decrease lead-time (Fujimoto, 1997). In other words, joint problem solving improves the design of related components, manufacturing process, and cost management. Therefore, joint problem solving is a critical key to achieve a high level of product integrity in development process (Takeishi, 2001).

Moreover, flexible response in problem solving, adequate expertise to solve the product design and process problems, and value analysis in problem solving are some other factors to be considered in order to evaluate the “problem solving capability” of both players in the process (Humphreys, 2003).

Early problem solving is a strategy that seeks to enhance development performance by shifting the identification and solving of the development process problems to earlier phases of product development process (Thomke and Fujimoto, 2000). In other words, implementing problem-solving techniques from the earlier stages of the collaborative product development process can improve the conformance of the outcome with the desired requirements. Therefore:

H5: *The early use of mutual problem-solving techniques between NPD team and suppliers is negatively associated with development lead-time in product development projects with supplier involvement.*

### **3.4 Knowledge and Product Development Project Performance**

According to open innovation theory, the company needs to open up its rigid boundaries to facilitate the flow of valuable knowledge from the outside of the firm to the inside. This helps the company to create opportunities for co-operative innovation processes with its partners such as customers and/or suppliers (Gassman and Enkel, 2004). Collaboration with different enterprises can also result in sharing technical knowledge and expertise (European Commission, 2000, Ledwith and Coughlan, 2005). Buyer-supplier team members are involved in many various tasks to develop a product collaboratively. They need to share or acquire knowledge in this process. In order to adapt knowledge residing in a partner, it is necessary to build close relationships in joint decision-making processes (Saxton, 1997; Bstieler, 2006).

Task interdependence and product complexity influence knowledge sharing procedure in the collaborative development process. The higher the degree of task interdependence is, the greater the coordinative and innovative information is needed to be shared among both parties in order to decrease technical information deficiency and ambiguity (Wageman, 1995; Sosa et al., 2002; Hoegle and Wagner, 2005). Product complexity is another factor which affects the type of buyer-supplier relationship and their knowledge sharing procedure (Kersten and Kern, 2003).

On the other hand, when assemblers only rely on suppliers' technological capabilities they may lose their "negotiation power" and their own expertise in core components area and the whole product integrity. This can put buyer organization in a vulnerable position in the

long term (Clark and Fujimoto, 1991). Therefore, supplier involvement in NPD projects can be beneficial “when a firm has internal knowledge and expertise to exploit the new knowledge and the commercial skills to manage its transfer” (Ledwith and Coughlan, 2005). The buyer organization needs to acquire appropriate knowledge –as the key element of organizational capabilities- towards the outsourced components in order to be able to evaluate the product and suppliers’ capabilities while being aware of the product consistency (Nonaka and Takeuchi, 1995; Takeishi, 2001).

Also, in a study of inter-firm collaboration in automobile development, Takeishi (2002) found that when an automaker’s engineers have higher degree of knowledge about the outsourced component, the design quality of the component increases significantly. When the buyer development team members have higher technical knowledge about the collaborative development project, they can participate more actively in problem identification and problem solving interactions with supplier members to reduce any possible deviation from the expected product requirements in the project. Moreover, buyer team members’ higher technical knowledge about the development project facilitates mutual problem solving process in terms of problem identification, idea exchange, knowledge sharing, and solution-seeking stages. Therefore, when buyer team members have higher technical knowledge, the positive effect of the intensive problem solving interactions on the product quality will improve. Correspondingly, the following hypotheses will be investigated in this study:

H6.1: *The buyer’s technical knowledge about the development project moderates the effect of intensive joint problem-solving on product quality. The higher the buyer*

organization *technical knowledge* about the development project is, the more effective is the impact of *intensive joint problem-solving interactions* on *product quality*.

H6.2: *The buyer's technical knowledge* about development project moderates the effect of *intensive joint problem-solving* on *development lead-time*. The higher the buyer organization *technical knowledge* about the development project is, the more important is the negative impact of *intensive joint problem-solving interactions* on *development lead-time*.

Also, buyer technical knowledge about the development project facilitates the flow of required information between buyer and supplier members. According to Kerzner (2003) effective communications among team members occur when they “get the right information to the right person at the right time and in a cost-effective manner” (Kerzner, 2003). Therefore, having a clear technical view about the product requirements enhances mutual understanding between CPD team members and improves their communication during the project progress. Thus the number of iterations deriving from misunderstanding and lack of mutual knowledge will decrease during development process. This can improve development lead-time. Therefore, we propose that:

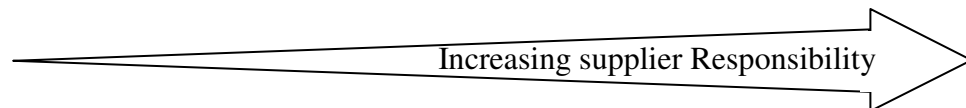
H6.3: *The buyer's technical knowledge* about development project moderates the effect of *intensive routine communication* on *development lead-time*. The higher the buyer organization *technical knowledge* about the development project is, the more important is the impact of *intensive routine communication* on *development lead-time*.

### 3.5 Supplier Responsibility in the CPD Process

In this research we try to find out whether the effect of collaborative product development team routine communication intensity and problem-solving interactions intensity vary depending on supplier's level of responsibility on the development process. Following the model of supplier level of responsibility suggested by Handfield et al. (1999) and Monczka et al. (2000) we investigate the extent to which supplier is integrated in the process trying to understand if it affects product quality considering the impacts of routine communication and problem solving interactions intensity. Level of responsibility is a "spectrum of supplier integration" from no involvement to the highest involvement in the development process (Petersen et al., 2005). Figure 3.1 shows this categorization of suppliers based on this spectrum.

**Figure 3.1- Spectrum of supplier integration (Petersen et al., 2005)**

None	"White Box"	"Gray Box"	"Black Box"
No Supplier involvement. Supplier 'makes to print'.	Informal supplier integration. Buyer "consults" with supplier on buyer's decision.	Formalized supplier. Joint development activity between buyer and supplier.	Design in Primarily supplier driven based on buyer's performance specifications.



The higher the supplier responsibility in the development process is the more intensive is the collaboration among buyer and supplier. This requires more routine communication and frequent problem solving interactions among the parties to exchange information during the progress of the CPD process. We therefore put forward the following two hypotheses:

H7.1: *Supplier responsibility* in development process moderates the effect of *routine communication intensity* on *product quality*. The higher *supplier responsibility* is, the more significant is the effect of *routine communication intensity* on *product quality*.

H7.2: *Supplier responsibility* in development process moderates the effect of *problem-solving interactions intensity* on *product quality*. The higher *supplier responsibility* is, the more significant is the effect of *problem-solving interactions intensity* on *product quality*.

### 3.6 Product Modularity

Modularity is a specific form of design that creates a high degree of independence or “loose coupling” between components by standardization of component interface designs (Sanchez and Mahoney, 1996). Moreover, organizations consider modularity as a means of managing complexity and designing flexible systems (Baldwin and Clark, 2000; Ethiraj and Levinthal, 2004). On the other hand, increasing product complexity leads firms to apply modularity more extensively. Product modularity designs require firms implementing vertical disintegration in design and production of product components and

sub-systems (Brusoni, 2005). However, when modularity increases, the number of interfaces will also increase. This can intensify complexity and the risk of failure in the collaborative product development process. Therefore, the higher degree of product modularity intensifies the significance of joint problem-solving interactions in order to detect unpredicted problems in the coupling of the interfaces during the process. The higher degree of product modularity can intensify the significance of coordination in buyer-supplier relationship and highlight the importance of frequent mutual joint problem-solving interactions in the collaboration. Thus we propose the following hypothesis:

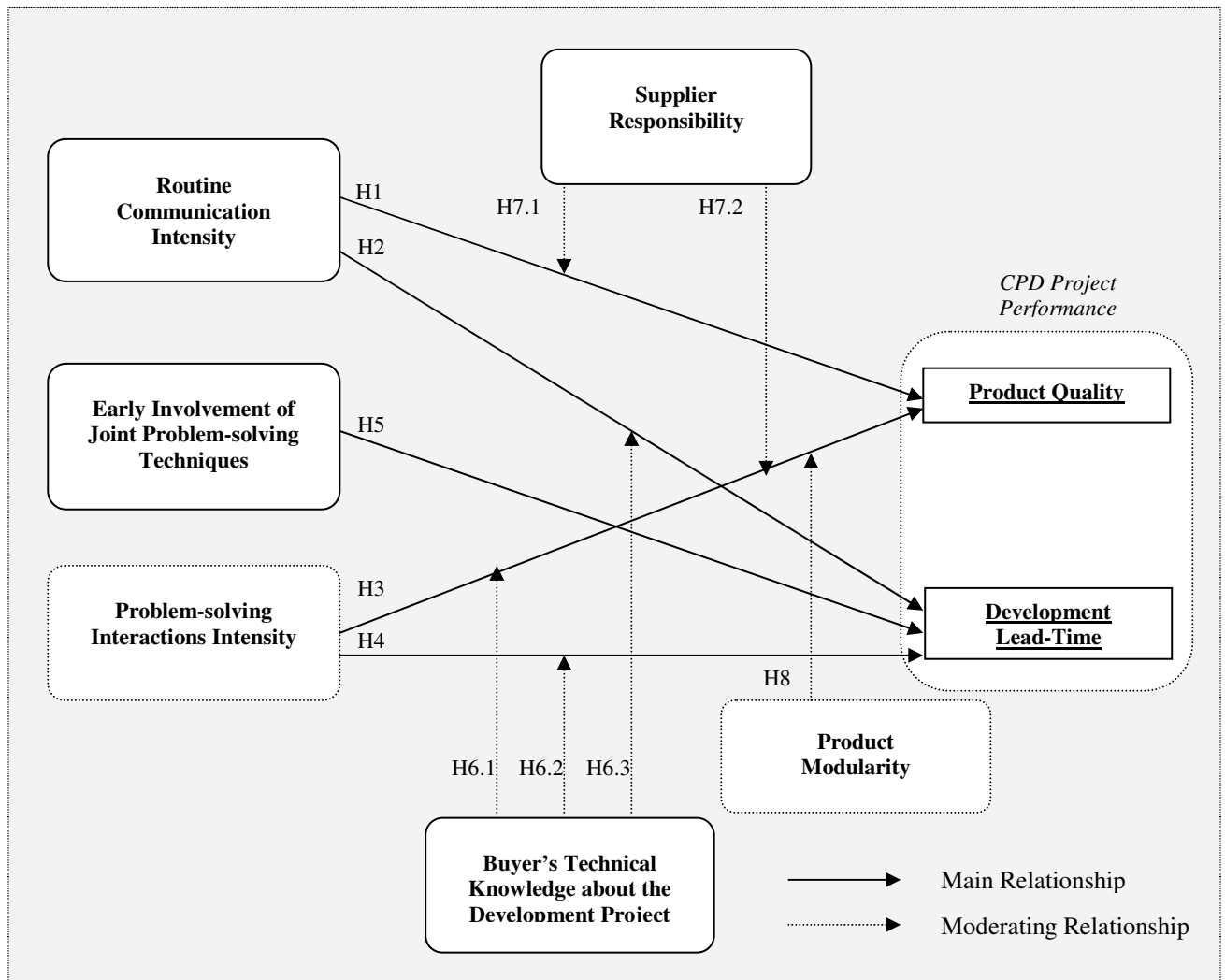
H8: *Product modularity* in development process moderates the effect of *problem-solving interactions intensity* on *product quality*. The higher the degree of product modularity is, the more significant is the effect of problem-solving interactions intensity on product quality.

### **3.7 Conclusion**

In this chapter, eleven hypotheses have been developed to explain how communication and problem-solving may affect the CPD process. Five direct relationships will be analyzed among routine communication intensity, problem-solving interactions intensity, early involvement of joint problem-solving techniques and the CPD performance criteria. Further, the moderating effects of supplier responsibility, product modularity and the buyer's technical knowledge will be evaluated on the related direct relationships.

Figure 3.2 shows the systematic overview of all the hypotheses which are presented in this section. The proposed hypotheses in this figure will be examined and analyzed in the further sections of the thesis.

Figure 3.2- Proposed Framework for Information Sharing in the CPD Process



## **Chapter 4 Research Methodology**

### **4.1 Introduction**

In this research we intend to investigate factors affecting information sharing in the collaborative product development process in buyer-supplier relationship. This chapter explains the research methodology we have chosen to test our hypotheses. Specifically, we describe the structure of the questionnaire, the concepts underlying the questionnaire design and the procedure of survey implementation to collect data. We elaborate all measures we used to evaluate dependent and independent variables in the model.

### **4.2 Research Methodology**

Quantitative research methodology is adopted for this study to investigate buyer-supplier relationship in the CPD process. This study tests the CPD process factors by the survey instrument to evaluate the concepts which are mostly introduced by theory building approach in the literature.

### **4.3 Questionnaire Design**

#### **4.3.1 The Structure of the Questionnaire**

A questionnaire was designed to test the proposed hypotheses in the framework in this research. In order to make the questionnaire easy and clear enough for respondents to read, the questionnaire was designed in a booklet format which consists of four pages in total (See Appendix A). In other words, one A3 size paper was folded in the middle to form a four-page booklet. Also, pink colour papers were used for the questionnaire booklet to make it eye-catching. Since the respondents were all from management level, different colour and size would make the questionnaire more distinguishable among all the documents they receive daily. In short, we tried to increase the managers' attention to spend enough time to participate in this survey by using different design for the questionnaire to stimulate their curiosity to read the questionnaire. Moreover, we tried to emphasize the importance of this survey by choosing an accurate and attractive template for the questionnaire while trying to make it economically reasonable to design, print, prepare and distribute.

This questionnaire consists of seven sections. The front page begins with a brief explanation of the objective and structure of the questionnaire while clarifying some expressions and measures applied in the questionnaire. In the beginning of the questionnaire, the respondents were asked to identify whether there had been any product development project which was collaboratively completed by supplier involvement within the last 12 months in their company or not. Then they were requested to continue to complete the whole questionnaire if they replied the above question positively. Otherwise, they were appreciated for their participation and asked

to go to the last section which included some general information about the company. In fact, this question was mentioned in the beginning to identify if the company has any collaboration with a supplier to be considered in this research project. To control any probable errors in the responses while providing similar definitions for all participants, we asked respondents to consider any collaborative product development project “in the last twelve months”. In the rest of the questionnaire respondents were required to express how much they might agree with specific sentences using the Likert scale. Therefore, respondents can show how intensively they may agree or disagree with the sentences mentioned in different sections to investigate buyer-supplier relationship in collaborative product development process. The Likert scale starts with one to seven describing respectively “strongly disagreement” to “strongly agreement” of the respondents’ viewpoints with the proposed sentences with four in the middle of the Likert scale spectrum to show neutral opinion.

The following figure shows the Likert scale used in the survey:

**Figure 4.1-** Likert Scale in this Research

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree

### 4.3.2 Question Construct

Most of the questions in this survey were designed closed-ended with ordered answer choices (Dillman, 1978). These questions ask respondents to consider the last product development in their company which has been completed collaboratively with a supplier. Closed-ended questions use the information provided by respondents to detect the extent to which each respondent may differ from every other one (Dillman,

1978). In this case, the responses are well suited for many forms of sophisticated analyses such as regression analysis. The questions use the same type of answer choices (e.g. strongly disagree to strongly agree) for many items.

### **4.3.3 Pre-test of the Questionnaire**

To ensure face validity of the questionnaire (Cook and Campbell, 1979), all measures were reviewed carefully by a group of experts in industry and university to justify the clarity and reliability of the questions mentioned in the survey. Accordingly, four professors whose research areas were related to this study participated in the review process to validate the content and wording of the questions. Moreover, six experienced industrial people investigated whether the questions wording and content are clear and meaningful to the potential respondents in industry. More specifically, three senior engineers in product development department, two R&D managers and one purchasing manager reviewed the questionnaire to enrich the reliability of the questions in this survey. All respondents were requested to explain their reactions to question form, wording and order. These explanations were noted down through either face to face interview or interactive email messages. The pre-test helped us determine whether the questionnaire is clear and understandable or not. It also let us identify some question defects such as ambiguity in the content or wording of the questions while analyzing possible “respondents’ cognitive difficulties” in answering the questions (Bolton, 1993). These comments help us improve the questionnaire and make it ready for the actual distribution among the chosen sample.

#### 4.3.4 Question Wording

All the knowledgeable experts examined the wording of the questions to make sure that (Dillman, 1978):

- Simple words have been chosen.
- Questions are short, specific and accurate.
- Questions are not biased.

The questionnaire was reviewed by the Institutional Review Board (IRB) in National University of Singapore which monitors the ethical aspects of NUS research projects which involve human subjects “to protect the rights and welfare of human research subjects in research activities conducted by NUS researchers” (NUS-IRB, 2004).

#### 4.4 Measures

Our framework consists of two dependent variables and six independent variables.

Table 4.1 shows all the variables in this study.

**Table 4.1- Variables in the Framework**

	Variable	Description
<b>Dependent Variables</b>	<b>PROQUL</b>	Product Quality
	<b>DEVTIME</b>	Development Lead-time
<b>Independent Variables</b>	<b>PROBINTER</b>	Problem-solving Interactions Intensity
	<b>EARLINVOLV</b>	Early Involvement of Joint Problem-solving Techniques
	<b>ROUTCOMM</b>	Routine Communication Intensity
<b>Moderators</b>	<b>DEGKNOW</b>	Buyer’s Degree of Knowledge about the Development Project
	<b>SUPRESP</b>	Supplier Responsibility
	<b>PROMODUL</b>	Product Modularity

#### **4.4.1 Dependent Variables**

There are two dependent variables in this research: product quality and development lead-time.

##### **4.4.1.1 Development Lead-time**

Development lead-time is a performance measure of competitive strategy. A company which launches a new product faster in the market benefits from obvious advantages. It can usually acquire premier market segments, build strong name recognition, and control a large market share (Duffy and Kelly, 1989; Shaker and Dian, 1993). Also, shorter product life cycles make firms respond more quickly and flexibly toward new technology, changes in consumer demands, and other competitive challenges. Therefore, firms try to reduce development lead-time as much as possible in NPD process. Since development lead-time is a standard concept in the literature, we just assigned one question to this concept to examine if the project is completed on time. Therefore, the following question measures development time in the survey in this research:

Q7: In this project we could meet the deadline in accordance with the planned schedule.

##### **4.4.1.2 Product Quality**

According to Garud (1997), product quality can be defined as “the collection of attributes, which when present in a product, means a product has conformed to or exceeded customer expectations.” Comparing different definitions argued in the

product quality literature, we adopted relative concepts from Garvin (1984)'s definition for product quality in this research.

Table 4.2 shows the measures applied in this survey to evaluate the quality of the product in the collaborative development process.

**Table 4.2- Product Quality Measures**

<b>Item</b>	<b>Questions</b>	<b>Reference</b>
<b>Functionality</b> (Product's operating characteristics)	Question 2 – Question 6	Garvin (1984)
<b>Dimensional Integrity</b> (Consistency and accuracy of dimensions of components)		
<b>Reliability</b> (The probability of a product's surviving over a specified period of time under stated conditions of use)		
<b>Conformance</b> (Conformance of the product specifications with the pre-established standards)		
<b>Durability</b> (The amount of use of a product before it deteriorates or needs replacement)		

#### **4.4.2 Independent Variables**

In this study, independent variables are the factors which may affect the CPD project performance in buyer-supplier relationship.

##### **4.4.2.1 Supplier Responsibility in the Project**

This variable evaluates supplier's level of responsibility in the buyer's new product development process. The degree of supplier responsibility in the CPD process may be different from 'no supplier involvement' in the process to the situations in which

“design is supplier driven based on buyer’s performance specifications” (Handfield et al., 1999; Karlsson, 1998; Liker, 1997; Monczka et al., 2000; Petersen et al., 2005).

Question 1 evaluates the level of supplier responsibility in the project by requesting the participants to rank the following statement:

Q1: This supplier was well integrated in this project as a joint development activity between the supplier and our company.

#### **4.4.2.2 Stage of Supplier Involvement**

In this study, we also try to investigate whether buyer-supplier relationship during routine communication and problem-solving interactions would be influenced by the stage of development process in which supplier is involved in the process. Therefore, respondents were asked about the stage or stages of the development process in which they might have any collaboration with their supplier in the project. In order to avoid any possible misconceptions about the meaning of different stages of development process, brief explanations followed the expressions to generally clarify the terms. Among all extensive definitions of development stages, we adopted Tidd and Bodley (2002)’s definition in this survey. Accordingly, the development stages were introduced in the questionnaire as follows:

- **Concept Generation** (Proposing, testing and analyzing a new idea based on market needs)
- **Product Definition** (Evaluation, selecting and planning product concepts)
- **Product Development** (Design, testing and prototyping activities)
- **Product Launch** (Product ramp-up, marketing, service & support development)

#### 4.4.2.3 Routine Communication Intensity

Routine communication intensity refers to the frequency of buyer-supplier interactions exchanging information about the progress of the project (Takeishi, 2002; Hoegl and Wagner, 2005). In fact, communication intensity can be measured by the frequency of the interactions between buyer and supplier in the process. Regarding Chong et al. (2007)'s framework, we also consider the following criteria to study communication intensity among product development teams (Table 4.3):

**Table 4.3- Routine Communication Intensity Measures**

Item	Questions	References
Openly exchange of ideas and information between buyer and supplier	Q9-Q13	Takeishi (2002)
Timeliness of the required information		Hoegl and Wagner (2005)
Accuracy of the information exchanged		Van der Valk and Wynstra (2005)
Proactiveness of suppliers in exchange of required information		Chong et al. (2007)

Thus questions eleven to fifteen were developed in the questionnaire on the basis of the above criteria to evaluate the intensity of routine communication in buyer-supplier relationship in CPD process:

Q9: Important ideas and information were exchanged openly between this supplier and our company during the project.

Q10: The overall atmosphere between this supplier and our company was cooperative.

Q11: The required information was exchanged on time between this supplier and our company.

Q12: The information exchanged between this supplier and our company was accurate.

Q13: The supplier was eager to communicate the required information with us during the process.

#### **4.4.2.4 Problem-solving Interactions Intensity**

Analyzing this construct, we aimed to study whether the frequency of problem-solving interactions between buyer and supplier may affect collaborative product development project performance in terms of product quality and development lead-time. Therefore, we tried to investigate if there had been frequent problem-solving sessions between buyer and supplier from early stages of development process. Questions sixteen, twenty and twenty two were designed for this reason.

Q14: When we encountered any unexpected mutual problems, we had frequent problem solving sessions with this supplier to find a solution.

Q18: We could identify foreseeable problems during our joint problem solving sessions with the supplier.

Q20: Our supplier frequently shared information with us to find feasible solutions mutually if any problems occurred during the project.

#### **4.4.2.5 Early Involvement of Problem-solving Techniques**

In this research we study not only the impact of intensive joint problem-solving pattern in buyer-supplier relationship but also the effect of early involvement of problem-solving techniques in the CPD process. For this reason, we studied the exchange of technical information (product specifications, design and engineering requirements, etc.) between buyer and supplier in development process to evaluate how the timing of

joint problem-solving techniques may affect buyer-supplier relationship and lead to different results in CPD performance. Therefore, we used two different criteria to measure this construct in our study on the basis of previous research in this area (Sosa et al., 2000; Takeishi, 2000):

**Table 4.4- Early Involvement of Problem-solving Techniques Measures**

Item	Questions	Reference
Clear engineering requirements for the supplier from the early stages of development	Q15- Q17, Q19	Sosa et al. (2000)
Buyer-supplier negotiation about the early engineering requirements		Takeishi (2002) Hoegl and Wagner(2005)

For this purpose, questions 15 to 17 and 19 were designed in the questionnaire:

Q15: The initial engineering requirements that we provided for the supplier were clear from the early stages.

Q16: The initial requirements we asked the supplier were stable and changed gradually during the further stages in the process.

Q17: We evaluated the supplier's manufacturing process and design for manufacturability from the early stages.

Q19: Earlier evaluation of foreseeable problems made the development process smoother.

#### **4.4.2.6 Buyer's Degree of Knowledge about the Development Project**

This construct refers to the degree to which buyer organization retains required knowledge for developing the product (Takeishi, 2002). Further criteria are used in this research to study the influence of buyer's technical knowledge on the CPD performance (Garud, 1997; Takeishi, 2002; Hoegl and Wagner, 2005):

**Table 4.5- Buyer's Degree of Knowledge Measures**

Item	Questions	References
Clear understanding of supplier's skills and technical capabilities	Q21-Q26	Garud (1997)
Clear understanding of manufacturability of design for the assembly purposes		Takeishi (2002)
Clear understanding of functional compatibility		Hoegl and Wagner (2005)
Clear understanding of the technological aspects of design the supplier apply		
Clear understanding of the functional and structural principles of design the supplier chooses		

Questions 21 to 26 were related to this construct:

Q21: From the early stages we had clear understanding of our supplier's skills and technical capabilities.

Q22: We evaluated the changes in our supplier's skills and technical capabilities during the project in order to be aware of their recent progress or decline.

Q23: We had clear understanding of manufacturability of design for assembly purposes in this project.

Q24: We had clear understanding of functional compatibility of the components designed collaboratively with the supplier in this project.

Q25: We had clear understanding of the technological aspects of design the supplier applied.

Q26: We had clear understanding of the supplier's project progress.

#### **4.4.2.7 Product Modularity**

Following Worren et al. (2005) we measured the degree of product modularity by asking the following questions from the respondents:

Q27: The product was made of separate modules in this project.

Q28: For this product, we could make changes in key components without redesigning other components.

Q29: We could reuse the components of this product for our other products easily.

Q30: We used a modular design approach to develop this product.

#### **4.5 Targeted Population**

This survey was conducted among manufacturing companies in Singapore. A list of companies was selected from two main recent databases in Singapore. A total of 464 manufacturing companies were chosen from the latest versions of Singapore 1000 list and Singapore Economic Development Board (EDB) which contain the general information of the companies in Singapore on the basis of their name, address, contact information, their products and nature of their business. These 464 companies were selected among all the companies considering their nature of business to examine if they have any product development activities or not. Among the 464 manufacturing companies, we called some of them randomly to improve our selected list by inquiring the companies to understand if they are involved in product development process or not. Following our research objectives, we focused on managers in product development or R&D department of the company. For some of the companies we found the name of the targeted person in Singapore 1000 and EDB lists. For some others, we searched their management board on their websites. Also, we randomly called the rest of the companies to check the name of their product development manager or any equivalent position to be targeted in this survey. For the companies

which we could not find the relevant manager, we sent the questionnaire to the managing director of the company requesting him to pass the questionnaire to the relevant manager. Following this strategy, we aimed to make sure that most of the respondents would be familiar with our research topic and they can contribute their accurate and updated information to our survey.

Also, we targeted five categories of manufacturing companies on the basis of UK standard industrial classification (SIC) codes. Therefore, the following five categories were considered in our study according to UK-SIC (2003):

**Table 4.6- SIC Codes Description**

<b>SIC Code</b>	<b>Description</b>
28	Fabricated Metal Product Manufacturing
29	Machinery Manufacturing
30	Computer and Electrical Product Manufacturing
31	Electrical Equipment, Appliance and Component Manufacturing
34	Transportation Equipment Manufacturing

The unit of analysis in this research was one project in each company which had been collaboratively completed by involving suppliers in development process.

### **4.6 Survey Implementation**

In choosing our survey population, we aim to investigate the impact of buyer-supplier relationship on the collaborative product development performance in terms of product quality and development lead-time.

After completing the list of the companies, a package was sent to the product development managers or those in similar positions in the company. Each package contained a cover letter, one questionnaire and one pre-paid envelop for the respondent to send the questionnaire back to the researcher. The cover letter was labelled with NUS letterhead explaining the objectives and benefits of this research project while elaborating necessary definitions of the applied expressions. The first round of questionnaires was sent to the 464 companies by registered mail. Following some previous studies, we used registered mail to distribute the questionnaires in order to intensify the significance of the survey and increase respondents' motivation to participate in the survey. Three weeks after the first distribution, reminder letters were sent to those companies which had not replied yet. The reminders also sent to the undelivered packages due to change of address or absence of the respondent after calling the companies to update necessary information. In this research, no incentives were provided for respondents to complete the questionnaire. However, we offered to send a summary of the final research findings to respondents in case they are interested.

### **4.7 Conclusion**

This chapter describes the structure and implementation of the survey instrument in details. Also, we presented all the variables required to verify our hypothesis according to the literature review and our theoretical framework. In the following chapter, we will analyze the collected data and discuss the findings in this survey.

# Chapter 5 Data Analysis and Discussion

## 5.1 Preliminary analysis

### 5.1.1 Response Rate

Out of 464 companies in our mailing list, 105 ones replied to us, 32 were undelivered due to changes in the address or absence of the targeted contact person in the company, and two companies changed their business recently (Table 5.1). Thus the response rate was 22% in this survey. Among the companies participated in this study, only 59 declared that they had been engaged in the collaborative product development process in the last 12 months. All 59 questionnaires were complete and reliable enough to be included in data analysis. Table 5.2 shows the response rate before and after sending reminders to the selected companies.

**Table 5.1- Outcomes of the Questionnaire Distribution**

<b>Statuses</b>	<b>Number</b>	<b>Response Rate (Out of All Companies)</b>
Total Sent	464	-
Undelivered	32	6.8%
Returned	105	22.62%
Returned (with Supplier Involvement)	59	12.71%
Returned (without Supplier Involvement)	46	9.91%

**Table5.2- Response Rate Overview**

			Response Rate Out of All Companies		Response Rate Out of Respondent Companies	
	After the 1 <sup>st</sup> Distribution	After Sending Reminders	After the 1 <sup>st</sup> Distribution	After Sending Reminders	After the 1 <sup>st</sup> Distribution	After Sending Reminders
<b>Returned</b>	65	40	14%	22%	62%	38%
<b>Returned (with Supplier Involvement)</b>	34	25	7.32%	12.71%	32.38%	56.19%
<b>Returned (without Supplier Involvement)</b>	31	15	6.68 %	9.91%	29.52%	43.81%

### 5.1.2 Respondents' Characteristics

The questionnaires aimed at the management in product development or R&D department in each company. For the companies which we could identify the name of the related manager in the databases, we sent the survey package directly to the person. In this case, the package and cover letter labelled with the name of the manager in charge of product development activities. Otherwise, we sent the package to the managing director of the company. For these cases, we requested the managing director to pass the questionnaire to the manager in charge of product development or R&D activities. Table 5.3 demonstrates the positions of the respondents in this study.

**Table 5.3- Position Description of the respondents**

<b>Position</b>	<b>Total</b>	<b>Percentage</b>
Product development Manager	21	35.6%
R&D Manager	9	15.25%
Purchasing/ Operation Manager	11	18.64%
Engineering Manager	5	8.47%
Managing Director	7	11.86%
Quality Manager	1	1.69%
Not Specified	5	8.47%

As depicted in Table 5.3, most of the respondents in this survey were product development and R&D managers who were involved in the product development projects directly (51%). So the data can be trusted for further analyses.

### 5.1.2.1 Industry Classification

Figure 5.1-Industry Categorization of the Respondent Companies

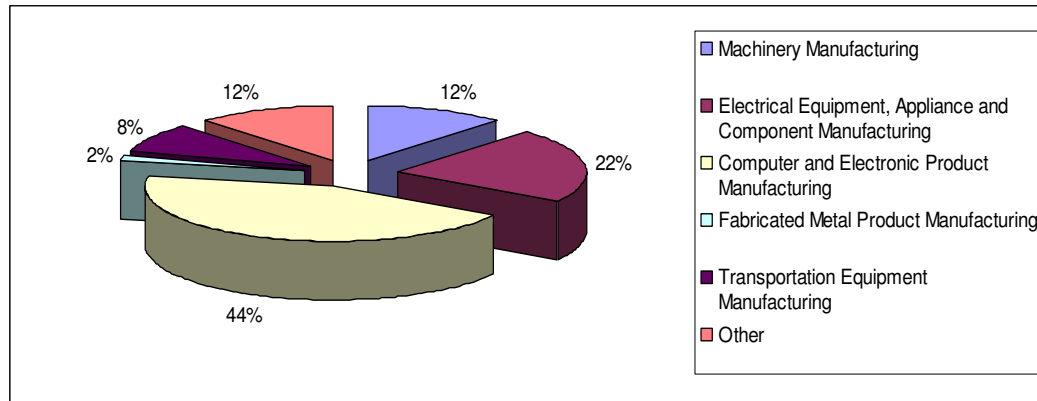
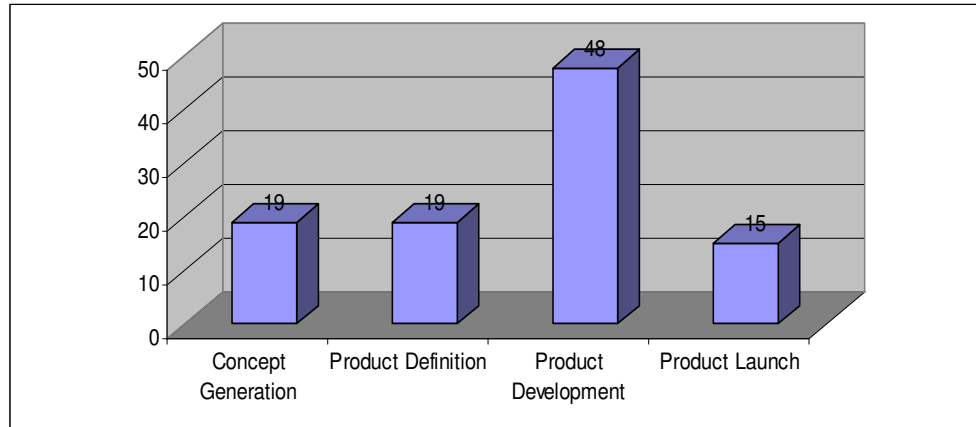


Figure 5.1 shows that variety of the industrial categorizations among the respondent companies. 66 percent of the companies belong to electrical and electronic product manufacturing.

### 5.1.2.2 Stage of Supplier Integration in the CPD Process

Based on the findings, 19 percent of the respondent companies integrated their supplier in the concept generation stage of the NPD process, 19 percent in the product definition stage, 47 percent in product development, and 15 percent in the product launch. Therefore, approximately 50 percent of the companies involved their supplier in the product development stage of the process to design, test, and make the prototype collaboratively (Fig. 5.2).

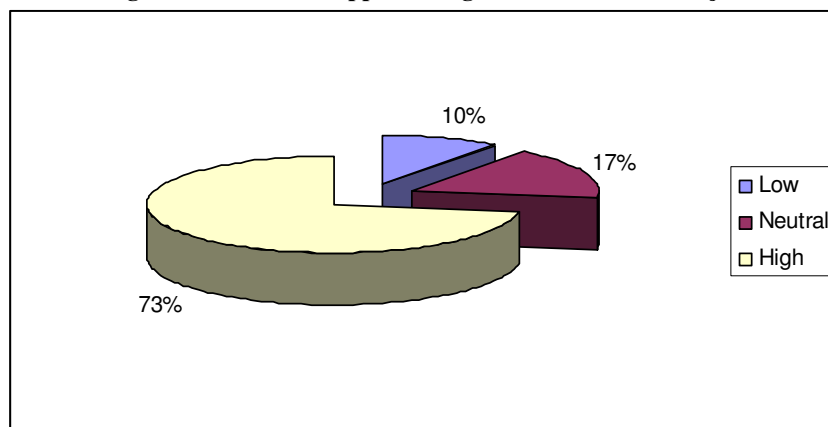
**Figure 5.2- Stage of Supplier Integration in the CPD Process**



### 5.1.2.3 Level of Supplier Responsibility in the CPD Project

The results show that 73 percent of the respondents claimed that the supplier in their recent CPD project had a high level of responsibility in the process while 10 percent declared that the supplier had a low level of responsibility during the process (Fig. 5.3). This figure shows that the level of supplier responsibility was high in most of the projects in our sample.

**Figure 5.3- Level of Supplier Integration in the CPD Project**



### 5.1.3 Non-respondent Bias Test

In this research, we did not have any information for non-responses. As there is no publicly available directory of companies with NPD activities, we had to use a general mailing list only with basic information. Although we tried to select the sample of companies on the basis of their nature of business, we could not make sure that all of them have product development activities. We did not have any criteria to find out whether these companies would collaborate with their suppliers in a project. Therefore, we did not conduct any non-response bias test.

### 5.1.4 Testing of the Survey Instrument

#### 5.1.4.1 Construct Reliability

The reliability of the questionnaire was tested by computing the Cronbach's alpha coefficient. The following formula was used to evaluate the Cronbach's alpha:

$$\alpha = \frac{N}{N-1} \times \left[ 1 - \frac{\sum \sigma_i^2}{\sigma^2} \right]$$

Where N is the number of the questions, say items, pertaining to the same hypothesis,

$\sigma_i^2$  is the variance of the number i item,  $\sigma^2$  is the sum of the item variances for all the items above. The rules of thumb for Cronbach's alpha reliability coefficient are as follows:

**Table 5.4- Cronbach's alpha reliability coefficient range (George and Mallery, 2003)**

Cronbach's $\alpha$	Reliability
$\alpha > 0.9$	Excellent
$\alpha > 0.8$	Good
$\alpha > 0.7$	Acceptable
$\alpha > 0.6$	Questionable
$\alpha > 0.5$	Poor
$\alpha \leq 0.5$	Unacceptable

Table 5.5 shows the reliability coefficients of the constructs in the framework in this study. As shown in this table, all the coefficients range from 0.72 to 0.87. Thus, all the proposed constructs are reliable in our proposed framework.

**Table 5.5- Cronbach's Alpha Reliability Coefficient**

Variable	Number of Items	Cronbach's Alpha
PROQUL	5	0.812
ROUTCOMM	5	0.853
PROBINTER	3	0.725
EARLINVOLV	4	0.768
DEGKNOW	6	0.874
PROMODUL	4	0.859
<i>DEVTIME</i> *	1	-

#### 5.1.4.2 Construct Validity

Construct validity evaluates the consistency between a theoretical concept (construct) and a corresponding measurement tool. It detects whether the constructs behave as they are expected to according to the proposed framework and the structure of the

constructs (De Vauss, 2002). In order to check construct validity we need to run convergent and discriminant validity. Convergent validity evaluates whether all the items in the construct are correlated with each other to examine if they are relevant to each other or not. On the other hand, discriminant validity examines the constructs which are conceptually different in the framework not to be related to each other.

#### 5.1.4.2.1 Convergent Validity

In order to assess convergent validity, we used factor analysis for all of the constructs in the framework. Principal Component Analysis (PCA) for each construct yielded a one factor solution for all constructs PROQUL, PROBINTER, EARLINVOLV, ROUTCOMM, DEGKNOW and PROQUL. Table 5.6 to table 5.11 show the component matrices for each of these constructs.

**Table 5.6- PROQUL Construct**

	<b>Component</b>
	1
<b>PROQUL1</b>	.780
<b>PROQUL2</b>	.632
<b>PROQUL3</b>	.823
<b>PROQUL4</b>	.786
<b>PROQUL5</b>	.800

**Table 5.7- PROBINTER Construct**

	<b>Component</b>
	1
<b>PROBINTER1</b>	.793
<b>PROBINTER2</b>	.817
<b>PROBINTER3</b>	.806

**Table5.8- EARLINVOLVE Construct**

	<b>Component</b>
	1
<b>EARLINVOLV1</b>	.739
<b>EARLINVOLV2</b>	.770
<b>EARLINVOLV3</b>	.876
<b>EARLINVOLV4</b>	.686

**Table5.9- ROUTCOMM Construct**

	<b>Component</b>
	1
<b>ROUTCOMM1</b>	.714
<b>ROUTCOMM2</b>	.897
<b>ROUTCOMM3</b>	.836
<b>ROUTCOMM4</b>	.769
<b>ROUTCOMM5</b>	.767

**Table 5.10- DEGKNOW Construct**

	Component
	1
<b>DEGKNOW1</b>	.714
<b>DEGKNOW2</b>	.723
<b>DEGKNOW3</b>	.745
<b>DEGKNOW4</b>	.903
<b>DEGKNOW5</b>	.819
<b>DEGKNOW6</b>	.837

**Table 5.11- PROMODUL Construct**

	Component
	1
<b>PROMODUL1</b>	.761
<b>PROMODUL2</b>	.625
<b>PROMODUL3</b>	.696
<b>PROMODUL4</b>	.735

The communality tables for the constructs show that each item explains a substantial percentage of variance of the construct (Table 5.12 to Table 5.17). However, communality for PROQUL is lower than the usual cut-off value of 0.5 for PROQUL2 which is dimensional integrity of components. Although this item is borrowed from the theory, it might not be clear and applicable to describe product quality in the industry categorizations in this study. Hence we omit this item from PROQUL scale.

**Table 5.12- Communalities for PROQUL**

	Initial	Extraction
<b>PROQUL1</b>	1	.609
<b>PROQUL2</b>	1	.399
<b>PROQUL3</b>	1	.677
<b>PROQUL4</b>	1	.618
<b>PROQUL5</b>	1	.639

**Table 5.13- Communalities for PROBINTER**

	Initial	Extraction
<b>PROBINTER1</b>	1	.630
<b>PROBINTER2</b>	1	.667
<b>PROBINTER3</b>	1	.649

**Table 5.14- Communalities for EARLINVOLV**

	Initial	Extraction
<b>EARLINVOLV1</b>	1	.546
<b>EARLINVOLV2</b>	1	.594
<b>EARLINVOLV3</b>	1	.768
<b>EARLINVOLV4</b>	1	.570

**Table 5.15- Communalities for ROUTCOMM**

	Initial	Extraction
<b>ROUTCOMM1</b>	1	.509
<b>ROUTCOMM2</b>	1	.804
<b>ROUTCOMM3</b>	1	.700
<b>ROUTCOMM4</b>	1	.591
<b>ROUTCOMM5</b>	1	.588

**Table 5.16- Communalities for DEGKNOW**

	Initial	Extraction
<b>DEGKNOW1</b>	1	.509
<b>DEGKNOW2</b>	1	.523
<b>DEGKNOW3</b>	1	.554
<b>DEGKNOW4</b>	1	.815
<b>DEGKNOW5</b>	1	.670
<b>DEGKNOW6</b>	1	.700

**Table 5.17- Communalities for PROMODUL**

	Initial	Extraction
<b>PROMODUL1</b>	1	.761
<b>PROMODUL2</b>	1	.625
<b>PROMODUL3</b>	1	.696
<b>PROMODUL4</b>	1	.735

#### **5.1.4.2.2 Discriminant Validity**

We observed that the correlations among items within the same construct showed higher correlation comparing to their correlation with items of other constructs. Since all items met this criterion, we can accept discriminant validity for the constructs.

#### **5.1.5 Test for Violation of the Assumptions of Multiple Regression Analysis**

According to Hair et al. (1998), four main assumptions underlying multiple regression analysis are:

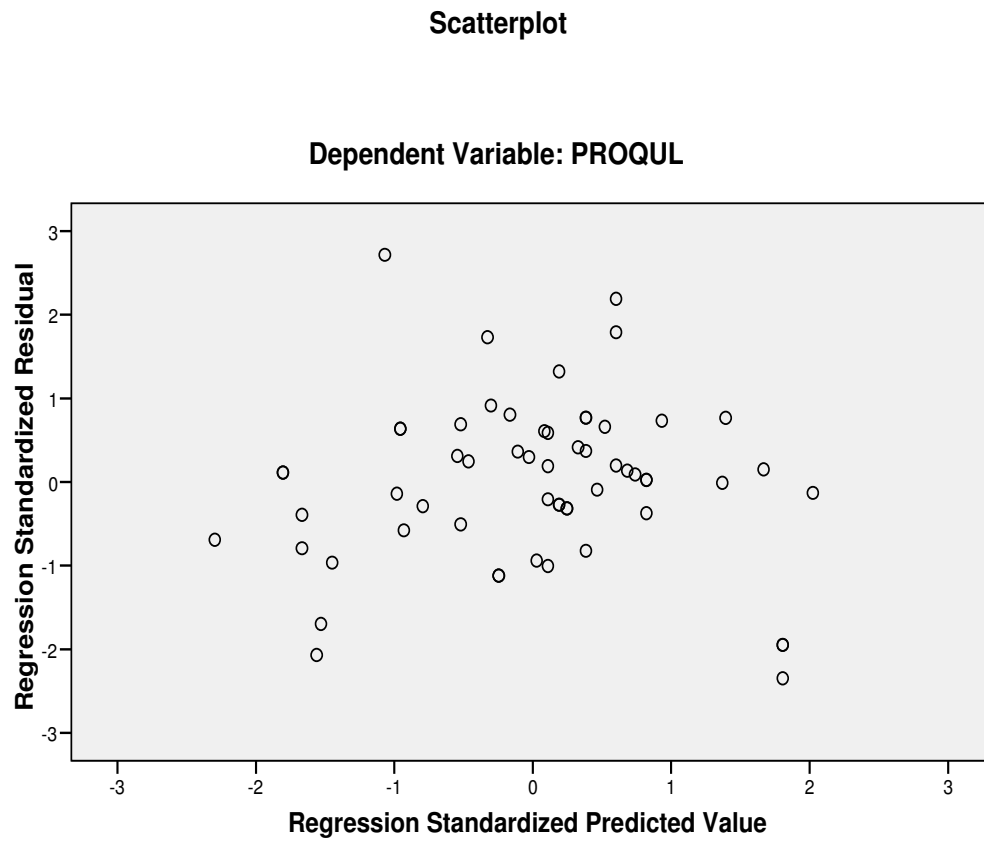
1. Linearity of the phenomenon measured
2. Constant variance of the error terms (Homoscedasticity)
3. Independence of observations (Multicollinearity)
4. Normality of the error terms distribution

We have two different dependent variables in our proposed framework. So we test the main assumptions of multiple regression analysis for each of these dependent variables: product quality (PROQUL) and development lead-time (DEVTIME).

##### **5.1.5.1 Constant Variance of the Error Terms (Homoscedasticity)**

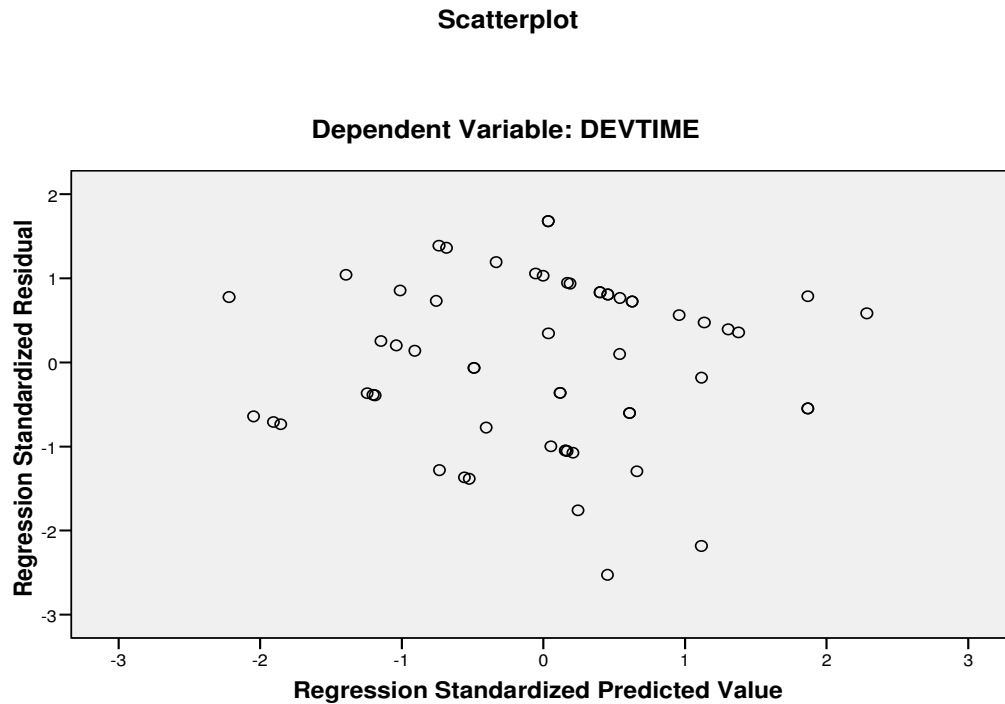
We examined the actual standardized residual values of each of the dependent variables (PROQUL and DEVTIME) versus the predicted residual values of these variables in a standardized scatter plot of the residuals in figure 5.4 and figure 5.5.

**Figure 5.4- PROQUL-Test of Homoscedasticity**



As shown in figure 5.4, the residuals fall between -2 and 2 and are randomly distributed in the straight bond about the horizontal straight line through zero. So no sign of heteroscedasticity was detected in the test (Chatterjee et al., 2002). Following the same logic, there is no sign of heteroscedasticity in the model related to DEVTIME (figure 5.5).

**Figure 5.5-DEVTIME- Test of Homoscedasticity**



#### **5.1.5.2 Test of Multicollinearity**

Collinearity is an undesirable situation where the correlation among the independent variables is high. It can be detected by the Tolerance static. The Tolerance statistic (t) is the proportion of a variable's variance that is not accounted for by other independent variables in the equation. A variable with low tolerance contributes little information to a model, and can cause problems (Kinnear and Gray, 2004). Variable inflation factor (VIF) is also another indicator to diagnose multicollinearity. If any variable has a tolerance of 0.2 or less or a VIF of 5 or more, there could be a sign of multicollinearity problem.

**Table 5.18- PROQUL - Test of Multicollinearity**

Variables	Collinearity Statistics	
	Tolerance	VIF
ROUTCOMM	.422	2.372
PROBINTER	.422	2.372

According to table 5.18, tolerance statistic is not low for both ROUTCOMM and PROBINTER and the variance inflation ratio (VIF) amounts are less than 5 for both of the variables. So there is no multicollinearity effect in this model.

**Table 5.19- DEVTIME- Test of Multicollinearity**

Variables	Collinearity Statistics	
	Tolerance	VIF
ROUTCOMM	.421	2.376
PROBINTER	.362	2.765
EARLINVOLV	.687	1.456

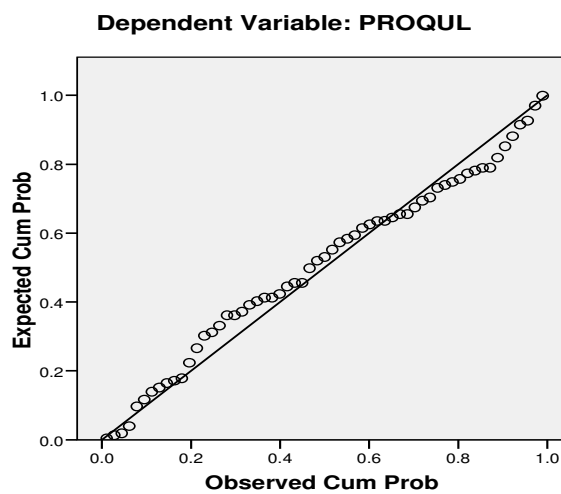
Table 5.19 summarizes the collinearity statistics for the main variables affecting development lead-time (the other dependent variable). Since Tolerance statistic is higher than 0.2 for EARLINVOLV, ROUTCOMM and PROBINTER variables, there is no multicollinearity effect in this model (De Vaus, 2003). Moreover, there is no sign of multicollinearity in the model since the variance inflation ratio (VIF) is less than 5 for the three independent variables.

### 5.1.5.3 Normality of the Error Term Distribution

Normal P-P plot demonstrates a normal distribution for the error terms (Fig. 5.6 and 5.7). It shows the standardized residuals against the standardized predicted values which indicate linearity and equality of variances.

**Figure 5.6- PROQUL-Test of Normality of the Error Term Distribution**

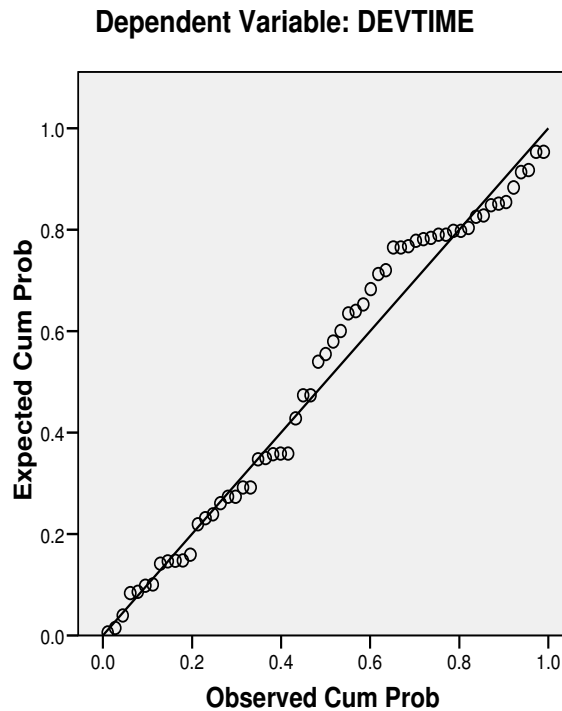
**Normal P-P Plot of Regression Standardized Residual**



Normal P-P plots of standardized residual in figures 5.6 and 5.7 show a normal distribution of the error terms for either of the dependent variables (Product Quality and Development Lead-time).

**Figure 5.7- DEVTIME- Test of Normality of the Error Term Distribution**

**Normal P-P Plot of Regression Standardized Residual**



**5.1.5.4 Linearity of the Phenomenon Measured**

Considering the scatter plot of the standardized residual values, the NPP plot for standardized residual, and the VIF values for all the variables involved in the model, there were no signs of non-linearity.

All the underlying assumptions of multiple regression analysis are satisfied. Having shown the validity of the constructs, we are now ready to examine the research hypotheses.

## 5.2 Product Quality-Multiple Regression Models

### 5.2.1 Multiple Regression Model I

Model I was our original regression model to study the effect of the relevant independent variables (ROUTCOMM and PROBINTER) on the first dependent variable (PROQUL). In this model, the two independent variables (routine communication intensity and problem-solving interactions intensity) were entered into the regression to investigate the main effects.

Table 5.20 presents the descriptive statistics of the regression result. The adjusted R Square shows that about 37.2 percent of the total variation in the product quality can be explained by the independent variables we introduced in the framework. Both of the regression coefficients are significantly different from zero.

**Table 5.20- Regression Model I-Model Summary (b)**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Sig.
1	.628(a)	.394	.372	.50220	.000

a. Predictors: (Constant), PROBINTER, ROUTCOMM

b. Dependent Variable: PROQUL

**Table 5.21- Model I Coefficients**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.553	.498		5.131	.000
	ROUTCOMM	.312	.116	.367	2.684	.010
	PROBINTER	.263	.103	.348	2.548	.014

a. Dependent Variable: PROQUL

### 5.2.2 Multiple Regression Model II

In order to test the moderating effects of the proposed moderators in the model (DEGKNOW, SUPRESP and PROMODUL), the interaction terms of the independent variables and moderators (e.g., DEGKNOW \* PROBINTER) were entered to test for

any moderating effects. A moderator hypothesis is usually supported when the interaction is significant regardless of any main effects (Bstieler, 2005; Baron and Kenny, 1986).

To evaluate the moderating effect of buyer's technical knowledge on the effect of problem-solving interactions intensity on product quality, we entered DEGKNOW and PROBINTER\*DEGKNOW to the model (Table 5.22).

As shown in Table 5.23, the interaction between DEGKNOW and PROBINTER is not significant as the significance is 0.189. Table 5.24 reveals that there is no sign of multicollinearity in the Model II.

Table 5.22- Regression Model II-Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Sig.
1	.678(a)	.459	.419	.48301	.000

a. Predictors: (Constant), PROBKNOW, PROBINTER, DEGKNOW, ROUTCOMM

Table 5.23- Model II Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.046	.071		.640	.525
	PROBINTER	.179	.121	.241	1.482	.144
	ROUTCOMM	.207	.136	.242	1.527	.133
	DEGKNOW	.189	.098	.254	1.932	.059
	PROBINTER*DEGKNOW	-.102	.077	-.136	-1.330	.189

a. Dependent Variable: PROQUL

Table 5.24- Model II Test of Multicollinearity

Variables	Collinearity Statistics	
	Tolerance	VIF
PROBINTER	.378	2.647
ROUTCOMM	.400	2.499
DEGKNOW	.577	1.732
PROBINTER*DEGKNOW	.964	1.038

### 5.2.3 Multiple Regression Model III

In order to investigate the moderating effect of supplier responsibility on the effect of problem-solving interactions intensity and routine communication intensity on product quality, we entered SUPRESP and its two interactions (ROUTCOMM\*SUPRESP and PROBINTER\*SUPRESP) to the model. Table 5.26 illustrates that the interaction between PROBINTER and SUPRESP is significant while the interaction between ROUTCOMM and SUPRESP is not. Table 5.27 shows that there is no multicollinearity problem in this model.

**Table 5.25- Regression Model III-Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Sig.
1	.748 (a)	.560	.518	.43990	.000

a. Predictors: (Constant), ROUTRESP, ROUTCOMM, SUPRESP, PROBINTER, PROBRESP

**Table 5.26- Model III Coefficients**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.138	.065		2.126	.038
	PROBINTER	.232	.110	.313	2.121	.039
	ROUTCOMM	.302	.122	.353	2.476	.017
	SUPRESP	-.036	.048	-.084	-.748	.458
	PROBINTER* SUPRESP	-.203	.080	-.421	-2.540	.014
	ROUTCOMM*SUPRESP	.001	.090	.002	.011	.991

a. Dependent Variable: PROQUL

**Table 5.27- Model III Test of Multicollinearity**

Variables	Collinearity Statistics	
	Tolerance	VIF
PROBINTER	.382	2.619
ROUTCOMM	.408	2.449
SUPRESP	.653	1.532
PROBINTER*SUPRESP	.302	3.309
ROUTCOMM*SUPRESP	.316	3.167

### 5.2.4 Multiple Regression Model IV

Model IV includes the moderating effect of product modularity on the impact of problem-solving interactions intensity on product quality. PROMODUL and PROBINTER\*PROMODUL were entered to the model. This interaction is also found to be significant in Model IV (Table 5.29). There is no multicollinearity problem in the model (Table 5.30).

**Table 5.28- Regression Model IV-Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.671 (a)	.451	.410	.48688

Predictors: (Constant), PROBMODUL, ROUTCOMM, PROMODUL, PROBINTER

**Table 5.29- Model IV Coefficients**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.079	.071		1.101	.276
	PROBINTER	.290	.129	.390	2.255	.028
	ROUTCOMM	.253	.133	.296	1.900	.063
	PROMODUL	-.001	.059	-.001	-.012	.991
	PROBINTER* PROMODUL	-.117	.050	-.240	-2.346	.023

a. Dependent Variable: PROQUL

**Table 5.30- Model IV Test of Multicollinearity**

Variables	Collinearity Statistics	
	Tolerance	VIF
PROBINTER	.339	2.946
ROUTCOMM	.420	2.382
PROMODUL	.648	1.544
PROBINTER*PROMODUL	.976	1.025

### 5.2.5 Multiple Regression Model V

Model V includes all the independent variables, the moderators and all of their interactions to study the moderating effects of all the proposed moderators in comparison with each other (Bstieler, 2005). As shown in Table 5.31, PROBINTER is significant and ROUTCOMM is partially significant ( $p < 0.1$ ). On the other hand,

PROBINTER\*SUPRESP is the only significant interaction in the full model. Due to the combined effect of all the interactions in the model, other interactions are not shown to be significant while some of them were significant when they were studied individually in the previous models.

Table 5.31- Regression Model V-Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.775(a)	.600	.527	.43592

a. Predictors: (Constant), PROBMODUL, SUPRESP, DEGKNOW, ROUTRESP, PROMODUL, ROUTCOMM, PROBKNOW, PROBINTER, PROBPRES

Table 5.32- Model V Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.112	.067		1.669	.102
	PROBINTER	.199	.094	.267	2.107	.040
	ROUTCOMM	.248	.126	.289	1.970	.055
	PROMODUL	-.029	.058	-.062	-.503	.617
	PROBINTER*PROMODUL	.028	.083	.058	.341	.735
	DEGKNOW	.166	.123	.223	1.350	.183
	PROBINTER*DEGKNOW	.050	.112	.067	.450	.655
	SUPRESP	-.033	.048	-.077	-.679	.500
	PROBINTER*SUPRESP	-.237	.090	-.492	-2.638	.011
	ROUTCOMM*SUPRESP	.016	.091	.029	.178	.859

a. Dependent Variable: PROQUL

Table 5.33- Model V Test of Multicollinearity

Variables	Collinearity Statistics	
	Tolerance	VIF
PROBINTER	.298	3.354
ROUTCOMM	.379	2.640
PROMODUL	.542	1.844
ROBINTER*PROMODUL	.283	3.528
DEGKNOW	.507	1.972
PROBINTER*DEGKNOW	.370	2.704
SUPRESP	.636	1.572
PROBINTER*SUPRESP	.235	4.259
ROUTCOMM*SUPRESP	.305	3.275

### 5.2.6 Product Quality- Summary of the Multiple Regression Models

Table 5.34 summarizes the results of Model I to Model V. In all models, product quality is the dependent variable.

**Table 5.34- Regression Results for Factors Related to the Product Quality**

	Model I	Model II	Model III	Model IV	Model V
<b>Main Effects</b>					
Problem-solving Interactions Intensity (PROBINTER)	.348**	.241	.313	.390	.267**
Routine Communication Intensity (ROUTCOMM)	.367**	.242	.355	.296	.289*
<b>Moderators</b>					
Buyer's Technical Knowledge (DEGKNOW)		.254			.223
Supplier Responsibility (SUPRESP)			-.084		-.077
Product Modularity (PROMODUL)				-.001	-.062
<b>Interactions</b>					
PROBINTER * DEGKNOW		-.136			.67
PROBINTER* SUPRESP			-.421**		-.492**
ROUTCOMM*SUPRESP			.002		.029
PROBINTER * PROMODUL				-.240**	.058

Significant at \* $p < .1$ , Significant at \*\* $p < .05$ , Significant at \*\*\* $p < .01$

## 5.3 Development Lead-time -Multiple Regression Models

### 5.3.1 Multiple Regression Model I

Similar analyses were implemented for the other dependent variable (DEVTIME). All the three main effects were entered to the model I to study their impact on development lead-time. Table 5.36 indicates that ROUTCOMM is partially significant ( $p < 0.1$ ) while PROBINTER and EARLINVOLV are not significant.

**Table 5.35- Regression Model I**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.447 (a)	.200	.157	1.49958

a. Predictors: (Constant), EARLINVOLV, ROUTCOMM, PROBINTER

**Table 5.36- Model I Coefficients**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.002	.195		-.012	.990
	PROBINTER	.462	.384	.242	1.205	.234
	ROUTCOMM	.699	.410	.317	1.703	.094
	EARLINVOLV	-.409	.253	-.235	-1.615	.112

a. Predictors: (Constant), PROBKNOW, EARLINVOLV, ROUTCOMM, DEGKNOW, PROBINTER

a. Dependent Variable: DEVTIME

**Table 5.37- Model I Test of Multicollinearity**

Variables	Collinearity Statistics	
	Tolerance	VIF
PROBINTER	.362	2.765
ROUTCOMM	.421	2.376
EARLINVOLV	.687	1.456

### 5.3.2 Multiple Regression Model II

Buyer's technical knowledge is the only moderator which may affect development lead-time in our framework. Model II includes the three independent variables (PROBINTER, ROUTCOMM, and EARLINVOLV), the moderator (DEGKNOW) and the two interactions (PROBINTER\* DEGKNOW and ROUTCOMM\* DEGKNOW). According to Table 5.39, the interaction between PROBINTER and DEGKNOW is significant.

**Table 5.38- Regression Model II**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.598 (a)	.358	.297	1.36880

a. Predictors: (Constant), ROUTKNOW, EARLINVOLV, ROUTCOMM, DEGKNOW, PROBINTER

**Table 5.39- Model II Coefficients**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.347	.211		1.647	.106
	PROBINTER	.461	.366	.241	1.262	.213
	ROUTCOMM	.780	.420	.353	1.854	.069
	EARLINVOLV	-.135	.295	-.078	-.458	.649
	DEGKNOW	-.473	.355	-.247	-1.332	.189
	ROUTCOMM* DEGKNOW	-.019	.582	-.007	-.033	.974
	PROBINTER* DEGKNOW	-.779	.431	-.401	-1.810	.076

b. Dependent Variable: DEVTIME

**Table 5.40- Model II Test of Multicollinearity**

Variables	Collinearity Statistics	
	Tolerance	VIF
PROBINTER	.338	2.954
ROUTCOMM	.340	2.939
EARLINVOLV	.429	2.329
DEGKNOW	.361	2.773
ROUTCOMM*DEGKNOW	.245	4.075
PROBINTER*DEGKNOW	.252	3.969

### 5.3.3 Development Lead-time- Summary of the Multiple Regression Models

Table 5.41 summarizes the results of Model I and Model II. In all models, product quality is the dependent variable.

**Table 5.41- Regression Results for Development Lead-time**

	<b>Model I</b>	<b>Model II</b>
<b>Main Effects</b>		
Problem-solving Interactions Intensity (PROBINTER)	.242	.241
Routine Communication Intensity (ROUTCOMM)	.317*	.353*
Early Involvement (EARLINVOLV)	-.235	-.078
<b>Moderators</b>		
Buyer's Technical Knowledge (DEGKNOW)		-.247
<b>Interactions</b>		
ROUTCOMM * DEGKNOW		-.007
PROBINTER * DEGKNOW		-.401*

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Significant at \* $p < .1$ , Significant at \*\* $p < .05$ , Significant at \*\*\* $p < .01$

## 5.4 Discussion of Research Findings

The results of the regression analysis provide support for hypothesis 1. As expected in our research, the effective impact of intensive routine communication on the product quality was justified. In fact, buyer and supplier focus on instrumental use of information during routine communication process (Citrin et al., 2007). They apply acquired information directly to make decisions about the tasks which are relatively structured. When they exchange the required information frequently, openly, accurately and proactively at the right time during the process, they can update each other about the project progress continuously to share clear mutual understanding about every stage of their collaboration. Buyer organization needs to communicate with the supplier routinely even though when such practice does not seem to bring any

obvious benefits immediately. Managers in charge of the CPD project may find it effective to facilitate frequent, open, accurate and proactive communication among buyer and supplier development team members in order to enhance the project performance.

Also, the effect of intensive routine communication on development lead-time was found to be significant but, surprisingly, in the opposite direction in this study. According to the findings, intensive communication can increase development lead-time. One possible reason is that most of our respondents are SMEs (65 percent) which often have limited resources, or have a small NPD departments (73 percent of the respondents have less than 50 full-time R&D or product development employees). Hence while communication with suppliers is helpful in general, “over” communication on routine and non-crucial information can increase the development time.

Our data analysis has further indicated that intensive problem-solving interactions with suppliers may enhance product quality in the collaborative product development process. In fact, problem-solving procedure deals with ambiguous and unpredicted situations during development process. In order to find proper meanings and solutions for these types of problems, the product development team members need to integrate new information into their current knowledge base. Thus intensive problem-solving interactions help companies concentrate on the conceptual use of information in order to find some innovative implications to improve product quality collaboratively (Citrin et al., 2007). It is also based on the commitment to and understanding of the information before its application to decision making (Beyer and Trice, 1982; Fredrickson, 1985). Buyer-supplier frequent interactions in problem-solving process

provide them with the opportunity to share knowledge with each other in order to achieve proper solutions for unpredicted problems during the process. It is suggested that buyer and supplier team members frequently exchange their new solutions and heuristics during their problem solving interactions in the process.

On the other hand, no evidence was found to support that intensive problem-solving interactions may decrease development lead-time. According to Sosa et al. (2002), distance, time zone and cultural/language difference have negative impact on technical information sharing in geographically distributed companies regardless of different types of information channels. Given the international nature of Singapore environment, many buyer-supplier transactions are likely to occur among dispersed entities. The differences in organizational cultures, languages and time zones may neutralize the impact of intensive problem-solving interactions on improving development lead-time (Bstieler, 2006).

Our fifth hypothesis proposes that the early use of mutual problem-solving techniques between buyer and supplier can decrease development lead-time. In contradiction to our prediction, early engagement of problem-solving techniques in CPD process may not necessarily improve development lead-time. Our data analysis reveals that more than half of our respondents involved suppliers in the product development or later stages (85 percent). This suggests that the product specification may have been well defined. As such, the contribution of supplier in NPD might have been taken into account when planning the project plan. Indeed, Baully (2000) found that as a whole the development activities in Singapore remain fair simple, or, incremental in nature. Hence, the early use of problem solving techniques does not have any significant impact on the development lead-time.

We examined three sources of information which may affect information sharing interactions in the collaborative product development process: buyer organization related factor, supplier organization related factor and product related factor. More specifically, we studied the effect of the buyer technical knowledge, the level of supplier responsibility and the level of product modularity on the impact of intensive communication and problem-solving interactions on the collaborative product development project performance.

The analysis does not provide support for H6.1. So we can not claim that the higher the buyer technical knowledge about the development project is, the more effective is the impact of intensive joint problem solving interactions on product quality. However, the previous literature suggests buyer organization not relying heavily on supplier expertise and knowledge but increasing their awareness about the development process even in the stages that they have involved their supplier to be responsible for the process. In fact, if a firm relies on its supplier heavily, it may be at risk of losing its own capability to differentiate itself from other competitors who may also collaborate with the same supplier. This risk is especially considerable in modular product development in which a specific supplier may collaborate with several firms to develop similar modules (Takeishi, 2001). However, our results do not support this hypothesis. There maybe two possible reasons. First of all, most of the companies which participated in our study are small and medium organizations which may not have enough resources to concentrate on problem-solving in their collaborations with the supplier. Second, our data analysis reveals that 51 percent of the companies developed modular product in their recent NPD project. Standard interfaces between different components of the product can reduce the number of sudden and unpredicted

problems which may happen during the process. Since the design interface is well developed the buyer's technical knowledge would not make a significant difference.

In addition, we found that buyer's technical knowledge moderates the relationship between the intensive problem-solving interactions and development lead-time but in the opposite direction than predicted in the model. One possible reason might be the deteriorating effect of potential conflicts which may occur between buyer and supplier during the process if they cannot converge their mutual understanding while facing a problem.

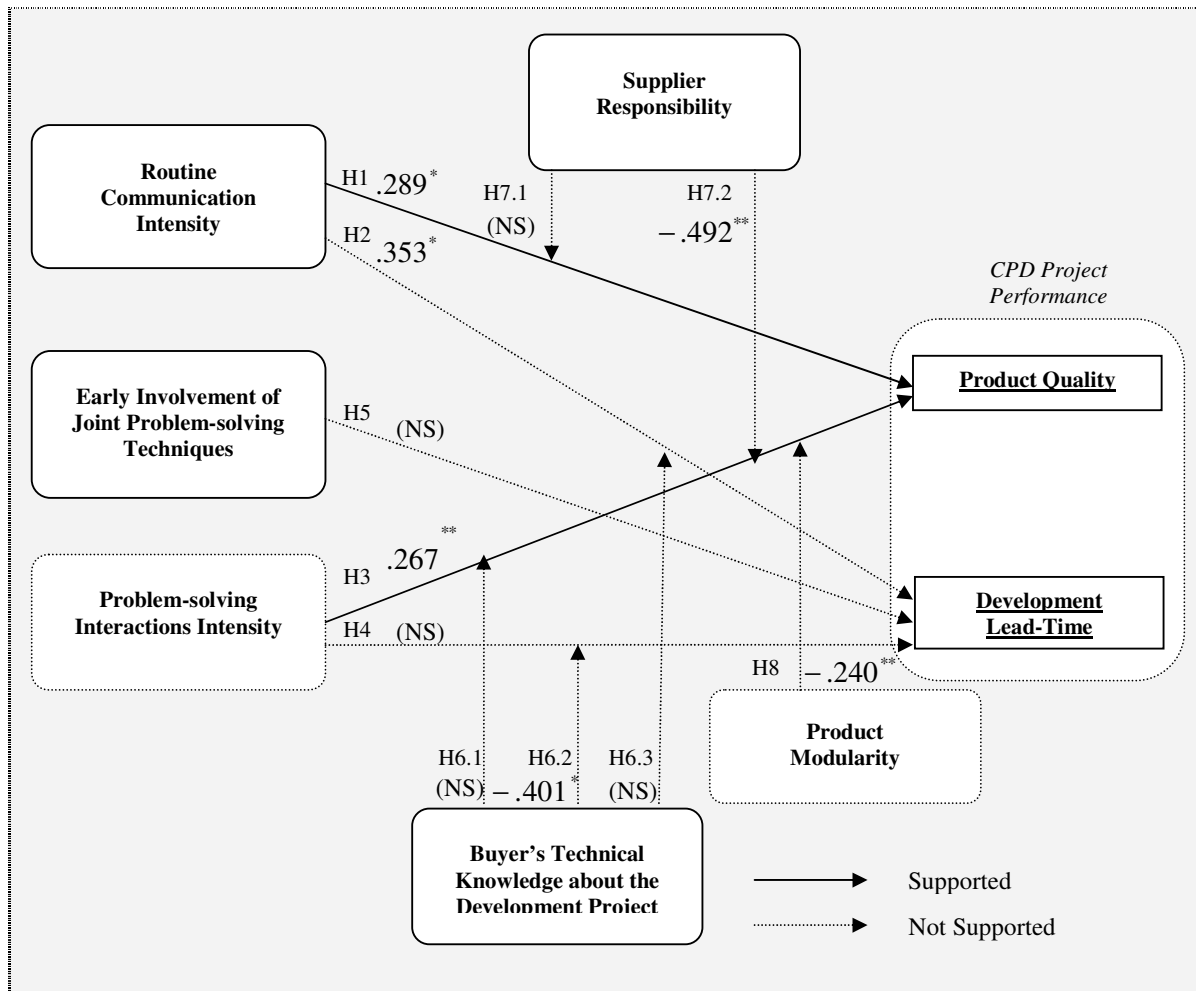
According to the findings, we could not find any evidence for moderating effect of buyer's technical knowledge on the interaction between routine communication intensity and development lead-time (H6.3). Our data analysis shows that 53 percent of the respondent companies are small and medium firms. It is more difficult for small firms to get cooperation from their suppliers in developing new products since they have lower purchasing power and production volumes (Ledwith and Coughlan, 2005). Consequently, buyer-supplier routine communication may not be influenced significantly by the buyer's technical knowledge. On the other hand, the assembly nature of the respondent companies may reduce the moderating effect of buyer's knowledge on the CPD performance.

We did not find any support to show that the level of supplier responsibility in the process moderates the impact of routine communication intensity on the product quality. One possible reason is that the information exchanged during routine communication is pre-defined in nature. Therefore, the intensity may not be moderated by the supplier's responsibility. However, the type or degree of confidentiality of the

information exchanged maybe moderated by the supplier responsibility. On the other hand, we found that supplier responsibility moderates the relationship between intensive problem-solving interactions and product quality but in the opposite direction than we predicted. The higher supplier responsibility is, the less significant is the effect of intensive problem-solving interactions on product quality. One possible explanation is that when the supplier responsibility is high, the supplier team members are more involved in decision making process during the development project and they may feel obligated to solve the problems on their own rather than relying on buyers. This sense of strong ownership may make them reluctant to accept suggestions from the other partners.

According to the findings, the moderating effect of product modularity on the direct effect of problem-solving interactions intensity on product quality is significant but in the opposite direction than predicted in the model. The data suggests that the higher the degree of product modularity is, the less significant is the effect of problem-solving interactions intensity on the product quality. Research in modular product development may explain that the more modular the product is, the more well-defined is the interface between the different modules. This will essentially reduce the need for interactions between the buyer and the supplier. The influence of problem-solving interaction on product quality will be reduced when the modularity is high. Since the interface is well defined, the buyer's or supplier's action is not likely to improve the product quality of their counterpart.

Figure 5.8- Proposed Framework for Information Sharing in the CPD Process



Significant at \*  $P < .1$ , significant at \*\*  $P < .05$ , (NS): Not Significant

## Chapter 6 Conclusion

### 5.5 Research Findings

Information is a significant resource for firms to help them develop new products successfully. Therefore, organizations need to rely on their capacity and their capability to use information effectively. According to the contingency theory, the organization's effective use of information for new product development depends on how well this information use fits into the firm's structure, process and its environmental context (Dubin, 1976; Ford and Slocum, 1977; Citrin et al., 2007). On the other hand, organizations nowadays are increasingly encountering external turbulence, uncertainty and complexity. Consequently, they need to manage two main challenges related to information: a greater amount of data to be analyzed and the ambiguity of information (Daft et al., 1993; Petersen et al., 2005). Organizations which involve suppliers in their product development process experience these two informational challenges more intensively since they face a greater amount of information to process and the higher degree of complexity due to the partnership. On the other hand, the main reason for involving suppliers into new product development projects is to access more helpful information earlier in the process by integrating the suppliers' knowledge and expertise into the process. However, this kind of collaboration increases the ambiguity and the amount of information the organization needs to manage (Huber, 1984). These organizations can access the greater volume of data by using communication and computing technologies, market research and boundary spanning departments. Yet, in order to make practical decisions, the accumulated information needs to be processed and analyzed by people who have

limited capacity to process a huge amount of information systematically (Tyler and Steensma, 1998). Hence providing managers with a great amount of information during collaborations does not necessarily facilitate their decision making process unless the information is both relevant and helpful. Managers who are in charge of collaborative product development projects try to find out what types of information are important to be considered in order to make more effective decisions to improve the collaborative product development project performance.

In this study, we investigated the effect of communication and problem-solving interactions on the collaborative product development (CPD) performance. We also studied whether the level of supplier responsibility moderates the impact of communication and problem-solving interactions on CPD performance. In addition, we scrutinized possible moderating effect of product modularity moderates the impact of problem-solving interactions on CPD performance.

The findings reveal that buyer-supplier intensive routine communication improves the collaborative product development performance. On the other hand, intensive problem-solving interactions do not improve the development lead-time though they have positive impact on the product quality in the CPD project.

It is also found that higher level of supplier responsibility in the CPD project decreases the improving impact of intensive problem-solving interactions on the product quality but it does not have any moderating effect on the way intensive routine communication affects the product quality.

Finally, when the degree of product modularity is high, intensive problem-solving interactions do not significantly enhance the product quality in the CPD project. Table 6.1 summaries our research findings.

Table 6.1- Summary of Research Findings

Hypothesis	Result
<i>H1</i> The intensity of routine communication between NPD team and suppliers has a positive relationship with product quality in product development projects with supplier involvement.	Supported
<i>H2</i> The intensity of routine communication between NPD team and suppliers has a negative relationship with development lead-time in product development projects with supplier involvement.	Not Supported
<i>H3</i> The intensity of problem-solving oriented interactions between NPD team and suppliers is positively associated with product quality in NPD projects with supplier involvement.	Supported
<i>H4</i> The intensity of problem-solving oriented interactions between NPD team and suppliers is negatively associated with development lead-time in product development projects with supplier involvement.	Not Supported
<i>H5</i> The early use of mutual problem-solving techniques between NPD team and suppliers is negatively associated with development lead-time in product development projects with supplier involvement.	Not Supported
<i>H6.1</i> The buyer's technical knowledge about the development project moderates the effect of intensive joint problem-solving on product quality. The higher the buyer organization technical knowledge about the development project is, the more effective is the impact of intensive joint problem-solving interactions on product quality.	Not Supported
<i>H6.2</i> The buyer's technical knowledge about development project moderates the effect of intensive joint problem-solving on development lead-time. The higher the buyer organization technical knowledge about the development project is, the more important is the negative impact of intensive joint problem-solving interactions on development lead-time.	Not Supported

## Chapter 6 Conclusion

<i>H6.3</i>	The buyer's technical knowledge about development project moderates the effect of intensive routine communication on development lead-time. The higher the buyer organization technical knowledge about the development project is, the more important is the impact of intensive routine communication on development lead-time.	Not Supported
<i>H7.1</i>	Supplier responsibility in development process moderates the effect of routine communication intensity on product quality. The higher supplier responsibility is, the more significant is the effect of routine communication intensity on product quality.	Not Supported
<i>H7.2</i>	Supplier responsibility in development process moderates the effect of problem-solving interactions intensity on product quality. The higher supplier responsibility is, the more significant is the effect of problem-solving interactions intensity on product quality.	Not Supported
<i>H8</i>	Product modularity in development process moderates the effect of problem-solving interactions intensity on product quality. The higher the degree of product modularity is, the more significant is the effect of problem-solving interactions intensity on product quality.	Not Supported

## 5.6 Implications

### 5.6.1 Implications for Researchers

The results from the survey on 59 high-tech companies in Singapore show that instrumental and conceptual use of information through routine communication and joint problem-solving interactions will influence the collaborative product development (CPD) project performance.

Our survey reveals that when the CPD project team-members face clear and well-defined situations or occasional ambiguous and unclear events, they can rely on the instrumental information through the routine communication to define the questions,

develop common understanding and gather data to find the answers during the process. However, when they need to analyze many ambiguous unclear events with high uncertainty, they should gather conceptual information through exchanging their solutions during the intensive joint problem-solving interactions in the process.

Our results suggest that in order to improve the CPD performance, it is also helpful to consider the extent to which supplier is responsible in the development process. This factor can influence the intensity of the interactions and the frequency of information flow among the two parties.

In conclusion, considering buyer's technical knowledge, product modularity, and supplier responsibility in the process seems to be important to decide how and when to interact with the supplier to enhance the project performance.

### **5.6.2 Implications for Practitioners**

Buyer-supplier collaboration is a complicated process during which both parties need to share different types of information. Managers usually face a great volume of information for making decisions in different stages of the CPD project. This study tries to suggest managers which factors they would better consider to make more efficient decisions to enhance the project performance. The findings of this research show that categorizing buyer-supplier interactions based on the type of the exchanged information can be helpful to manage buyer-supplier relationship. We tried to highlight the significance of both intensive routine communication and joint problem-solving on the project performance.

## Chapter 6 Conclusion

Our findings suggest buyer organizations to communicate with their suppliers routinely even though they may not find the clear and immediate benefits. In addition, they need to decide which routine communication is crucial to be taken into consideration regularly. This prioritization helps them avoid dealing with information overload which can increase development time. Collectively, H1 and H2 suggest it is a delicate act to decide how much communication should take place so that it does not delay the project and yet it helps to improve or maintain product quality.

It is also suggested that buyers can increase their problem-solving interactions with their suppliers to achieve higher product quality.

When suppliers are highly involved in the collaborative product development, buyers need to manage their mutual problem-solving interactions based on their competencies. They need to be aware of the negative impact of intensive problem-solving interactions on the product quality. This may help them find the main problems to focus instead of frequent problem-solving interactions. They need to find a balance to have efficient problem-solving sessions.

It may also be more effective to define the product requirements and the responsibilities of each side clearly upfront (especially in modular product development). This way, buyers do not need to invest much on intensive problem-solving interactions with suppliers to improve product quality during the modular product development process.

## **5.7 Limitations and Further Research**

Our findings introduce some areas for further research in the collaborative product development process.

Firstly, in our study, we found evidence to claim that the intensity of routine communication between NPD team and suppliers has a positive relationship with product quality in product development projects with supplier involvement. More investigations can explore the impact of the routine communication on the collaborative product development performance based on the pro-activeness, timeliness, and accuracy of buyer-supplier communication.

Secondly, it is also interesting to examine how routine communication may affect the impact of the problem solving and if it may reduce the need for problem solving interactions. In addition, further research can investigate if routine communication and problem solving interactions may have different priorities in different stages of the process when a problem occurs.

Thirdly, although our study reveals no support that the intensity of problem-solving oriented interactions between NPD team and suppliers is negatively associated with development lead-time, it can be helpful to investigate how the quality of problem solving interaction may affect the development lead-time.

It is also helpful to study different problem-solving techniques (such as TRIZ, Brainstorming, and Creative Problem-solving Process (CPS)) in buyer-supplier relationship to investigate how buyer's knowledge may improve the application of these techniques in different stages of development process.

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In contradiction to two of our propositions (H7.1 and H7.2), supplier responsibility in development process does not positively moderate either the effect of routine communication intensity or the effect of problem-solving interactions intensity on the product quality. However, it may be helpful to study if the type or degree of confidentiality of information exchanged would be moderated by the supplier responsibility. Also, further research can study the impact of mutual trust and conflicts on the collaborative project performance during the problem-solving interactions.

On the other hand, we focused on the information sharing in the collaborative product development process in this research. For this purpose, we mostly consider buyer-supplier interactions and explored communication and problem-solving activities among the parties while analyzing the impact of supplier responsibility, product modularity and buyer's technical knowledge on the interactions in our proposed framework. However, buyer-supplier interactions might also be affected by some other significant factors such as shared business and financial ties among parties, intellectual property, and sales dependency (Petersen et al., 2005). Including these factors in the framework to analyze possible interactions would result in more comprehensive outcomes and implementations for effective management of buyer-supplier relationship.

On the other hand, conflict among buyer-supplier team members especially in geographically distributed teams can influence the final outcome due to the distance among team members and their reliance on communication technologies (Hinds and Bailey, 2003). Investigating the impact of possible conflicts among the collaborative product development team may also enrich the findings of this study. Similarly, the role of communication technologies can be studied to add more insights to this study.

## Chapter 6 Conclusion

Finally, product modularity was measured based on some quantitative indicators in the literature. Using some qualitative questions in the questionnaire may add more in-depth insights to investigate the degree of product modularity. This may lead to more accurate data.

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## Appendix A- Questionnaire Administration

15 May 2007

***Name of the Recipient***  
**Name of the Company**  
**Address**

Dear Sir/ Madam,

We would like to invite your company to participate in a study on collaborative product development management. This is a research project conducted by the Engineering Management Group at the Industrial and Systems Engineering Department, National University of Singapore. The purpose of this study is to investigate the impact of supplier involvement on collaborative product development performance. We hope the findings will provide new understanding on collaborative product development.

For this purpose, we would be very grateful if you or your senior manager in charge of new product development projects (e.g. R&D director or product development project manager) could kindly complete the enclosed questionnaire. All responses will be treated in strict confidence and anonymity. Data analysis will be done at an aggregated level and will not traceable to any individual company. The names and identification of the companies and individuals will not be revealed.

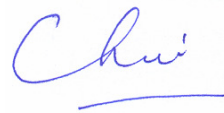
The questionnaire should take less than 20 minutes to complete. We would be very grateful if you submit the completed questionnaire either by fax or by mail using the envelope provided, preferably within the next 2 weeks (by June 1, 2007) . We will be happy to send you a summary of the findings should you be interested. Your decision to participate in this research is voluntary and you may withdraw from the research at any time without giving any reasons. Should you provide the contact details, we would be able to withdraw and discard your responses completely.

Please do not hesitate to contact us if you need any further information. Your dedicated time and effort in contributing your expertise to this research are greatly appreciated. Thank you in advance for your support in this survey.

Yours sincerely,



Shabnam Hajizamanali  
Email: [g0500722@nus.edu.sg](mailto:g0500722@nus.edu.sg)



Dr Chai Kah Hin  
Email: [iseckh@nus.edu.sg](mailto:iseckh@nus.edu.sg)

## Supplier Involvement in Collaborative Product Development

This survey is about **collaborative product development project** with **supplier involvement**. In this survey the term “supplier” describes any organization which has collaborated with your company to develop a new product. Your cooperation in this study helps us understand how to manage supplier relationship more effectively in collaborative product development process.

### Preliminary Stage

✓ Please identify if there has been any product development project collaboratively completed by **supplier involvement** within **the last 12 months** in your company.

☐ Yes ☐ No

If you have chosen “No”, please just complete **Section VII**. Thank you for your cooperation.

If you selected “Yes” for this question, **please consider a recent product development project with supplier involvement completed within the last 12 months**. Please answer the following questions regarding the relationship between your company and **a main supplier** involved in this project. Please answer **all** questions. When a precise answer is not possible, please provide your best estimate rather than leaving the answers blank.

Please consider the following metrics for answering the following questions:

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree

**I:** How much do you agree with the following statements about the level of supplier responsibility in this project?

	Strongly Disagree			Neutral			Strongly Agree
1. This supplier was well integrated in this project as a joint development activity between the supplier and our company.	1	2	3	4	5	6	7

**II:** This supplier was involved in the following stage/stages of the development process (you may choose more than one option if appropriate):

<input type="checkbox"/> Concept Generation (Proposing, testing and analyzing a new idea based on market needs)
<input type="checkbox"/> Product Definition (Evaluation, selecting and planning product concepts)
<input type="checkbox"/> Product Development (Design, testing and prototyping activities)
<input type="checkbox"/> Product Launch (Product ramp-up, marketing, service & support development)

**III:** How would you evaluate the **excellence** of the final product considering the following aspects?

	Very bad		Neutral			Very good	
2. Functionality (Product's operating characteristics)	1	2	3	4	5	6	7
3. Dimensional integrity (Consistency and accuracy of dimensions of components)	1	2	3	4	5	6	7
4. Reliability (The probability of a product's surviving over a specified period of time under stated conditions of use)	1	2	3	4	5	6	7
5. Conformance (Conformance of the product performance compared with the initial targets)	1	2	3	4	5	6	7
6. Durability ( The amount of use of a product before it deteriorates or needs replacement)	1	2	3	4	5	6	7

**IV:** How much do you agree with the following statements about the **development time**?

	Strongly Disagree		Neutral			Strongly Agree	
7. In this project we could meet the deadline in accordance with the planned schedule.	1	2	3	4	5	6	7
8. The project was completed after the expected deadline due to some unexpected problems.	1	2	3	4	5	6	7

**V:** How much do you agree with the following statements considering your relationship with this supplier during this project?

	Strongly Disagree		Neutral			Strongly Agree	
9. Important ideas and information were exchanged <u>openly</u> between this supplier and our company during the project.	1	2	3	4	5	6	7
10. The overall atmosphere between this supplier and our company was <u>cooperative</u> .	1	2	3	4	5	6	7
11. The required information was exchanged <u>on time</u> between this supplier and our company.	1	2	3	4	5	6	7
12. The information exchanged between this supplier and our company was <u>accurate</u> .	1	2	3	4	5	6	7
13. The supplier was <u>eager to communicate</u> the required information with us during the process.	1	2	3	4	5	6	7
14. When we encountered any unexpected mutual problems, we had <u>frequent</u> problem solving sessions with this supplier to find a solution.	1	2	3	4	5	6	7

15. The initial engineering requirements that we provided for the supplier were <u>clear from the early stages</u> .	1	2	3	4	5	6	7
16. The initial requirements we asked the supplier were stable and changed gradually during the further stages in the process.	1	2	3	4	5	6	7
17. We evaluated the supplier's <u>manufacturing process</u> and design for manufacturability from the early stages.	1	2	3	4	5	6	7
18. We could identify foreseeable problems during our <u>joint problem solving sessions</u> with the supplier.	1	2	3	4	5	6	7
19. <u>Earlier evaluation</u> of foreseeable problems made the development process smoother.	1	2	3	4	5	6	7
20. Our supplier <u>frequently</u> shared information with us to find feasible solutions mutually if any problems occurred during the project.	1	2	3	4	5	6	7
21. From the early stages we had clear understanding of our <u>supplier's skills and technical capabilities</u> .	1	2	3	4	5	6	7
22. We evaluated the changes in our supplier's <u>skills and technical capabilities</u> during the project in order to be aware of their recent progress or decline.	1	2	3	4	5	6	7
23. We had clear understanding of <u>manufacturability</u> of design for assembly purposes in this project.	1	2	3	4	5	6	7
24. We had clear understanding of <u>functional compatibility</u> of the components designed collaboratively with the supplier in this project.	1	2	3	4	5	6	7
25. We had clear understanding of the <u>technological aspects</u> of design the supplier applied.	1	2	3	4	5	6	7
26. We had clear understanding of the supplier's project <u>progress</u> .	1	2	3	4	5	6	7

**VI:** How much do you agree with the following statements to describe the final product in this project?

	Strongly Disagree		Neutral			Strongly Agree	
27. The product was made of separate modules in this project.	1	2	3	4	5	6	7
28. For this product, we could make changes in key components without redesigning other components.	1	2	3	4	5	6	7
29. We could reuse the components of this product for our other products easily.	1	2	3	4	5	6	7
30. We used a modular design approach to develop this product.	1	2	3	4	5	6	7

**Please turn to the next page.**

## Section VII: Background Information

**Part A:** Please provide the following information about your company.

31. Which industry does your company belong to?			
<input type="checkbox"/> Machinery Manufacturing	<input type="checkbox"/> Computer and Electronic Product Manufacturing		
<input type="checkbox"/> Electrical Equipment, Appliance and Component Manufacturing	<input type="checkbox"/> Fabricated Metal Product Manufacturing		
<input type="checkbox"/> Other (please specify): _____		<input type="checkbox"/> Transportation Equipment Manufacturing	
32. Please identify the product developed in this project (e.g. Mobile Phone, Inkjet Printer, Printed Circuit Board, etc.): _____			
33. Please identify the number of full-time employees in your company in Singapore:			
<input type="checkbox"/> Less than 50	<input type="checkbox"/> 50 – 100	<input type="checkbox"/> 101 – 250	
<input type="checkbox"/> 251 – 500	<input type="checkbox"/> 501 – 1000	<input type="checkbox"/> More than 1000	
34. Please identify the type of your company:			
<input type="checkbox"/> Local Company	<input type="checkbox"/> Multinational Company	<input type="checkbox"/> Joint Venture Company	
<input type="checkbox"/> Other (please specify): _____			
35. Please identify the number of full-time R&D and product development employees in your company in Singapore:			
<input type="checkbox"/> Less than 10	<input type="checkbox"/> 10-50	<input type="checkbox"/> 51-100	<input type="checkbox"/> 101-200
<input type="checkbox"/> 201-500	<input type="checkbox"/> 501-1000	<input type="checkbox"/> More than 1000	
36. Please identify your position in the company:			
<input type="checkbox"/> Product Development Manager	<input type="checkbox"/> R&D Manager		
<input type="checkbox"/> Operation Manager	<input type="checkbox"/> Other (Please specify): _____		
37. How many years have you been in this position in this organization?			
<input type="checkbox"/> Less than 1 year	<input type="checkbox"/> 1-3 years	<input type="checkbox"/> 4-6 years	
<input type="checkbox"/> 7-10 years	<input type="checkbox"/> More than 10 years		

**Part B:** If you would like to receive a summary of this survey, please provide the following information:

Name: _____	
Company: _____	
Address: _____ _____	
Postcode: _____	Fax: _____
Phone: _____	Email: _____

