Communication, Goals and Collaboration in

Buyer-Supplier Joint Product Design

by

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ABSTRACT

Original equipment manufacturers (buyers) are increasingly involving suppliers in new product development as a means to increase efficiency and expand capabilities. To realize such benefits, however, the two firms need to have appropriate communication and goal structures to minimize friction while maximizing design quality. In addition, the effectiveness of the inter-firm interaction process, i.e. their *collaboration quality*, is also a key success factor.

This study draws from Information Process Theory to propose that higher technical and relational uncertainty requires more inter-firm communication. The misalignment between communication intensity and uncertainty reduces both design quality and design efficiency. Goal incongruence, which always lowers project performance, is less harmful for projects with high technical uncertainty due to the potential of the conflict resolving process in improving decision quality and efficiency. Finally I use Hackman's theory of work group effectiveness to propose that collaboration quality fully mediates the effects of communication intensity and goal congruence on project outcomes.

The study used an empirical survey of manufacturers as the primary method of data collection. Manufacturers that integrate and assemble complex and discrete products are the target population. Design engineers and project managers from manufacturers were my target respondents. Both SEM and hierarchical regression were used to test the conceptual model.

The dissertation made five theoretical contributions. First, I introduced the concept that there is an optimal level of inter-firm communication intensity, exceeding which lowers design efficiency without improving design quality. Second, I theoretically defined and empirically operationalized two types of uncertainty, one on the project level and one on the inter-firm level, which were shown to moderate the effects of inter-firm communication and

goal structures on collaboration outcomes. Third, this study examined the conditions when goal congruence is more effective in improving collaboration outcomes. Fourth, this study nominally and operationally defined collaboration quality, a theoretical construct which measure the effectiveness of inter-partner interactions rather than mere existence or amount of certain activities pursued by partners. Finally, I proposed several enhancements to existing construct measures.

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1 OVERVIEW OF THE RESEARCH

1.1 Introduction

In their struggle to adapt successfully to the rapidly changing environment, many companies rely increasingly on inter-firm collaboration to overcome competence limitations, to leverage capabilities, and to be flexible while focusing internal resources on core competencies (Heimeriks and Schreiner 2002). Concurrently, the rapid rate of technological change, shortened product cycles, and the globalization of markets have led companies to focus on improving their new product development (NPD) processes (Handfield et al. 1999). Even during the current economic recession, senior executives are still upgrading their investments in innovation, according to the 2010 McKinsey Global Survey and the 2009 BCG Senior Executive Innovation survey These two forces are driving original equipment manufacturers (OEMs, referred to as buyers in the remaining text) to involve their component suppliers (referred to as suppliers in the remaining text) in NPD projects. Partnering with a supplier for innovation is believed to be a top driver of excellence, according to the 2009 BCG Senior Executive Innovation survey. Early supplier involvement in product innovation is shown to be one of the key profitability differentiators in the midst of the recent economic crisis (Harbour-Felax, 2009).

Supplier involvement in product development can be defined as the extent to which a buyer organization shares responsibility with a supplier organization for the development and design of subsystems (or components) of a new product (Takeishi, 2001). Suppliers could provide innovative product or process technologies that are critical to the novelty of the final product (Swink and Mabert 2000, Handfield et al. 1999, Azadegan et al. 2008). For example, Apple partners closely with its upstream suppliers to increase access to top product design talent; this type of arrangement gives OEMs access to skills they may not have in-house and allows them to leverage scarce engineering talent, in addition to shorter development cycle time (Grover, et al. 2008). Similarly, in an emailed response to Reuters questions, Boeing said that "Suppliers helped us develop and understand technologies and options for the airplane as we went through the early phases of concept development. Suppliers have also provided more of their own development, design and manufacturing funding." (Peterson, 2011, http://in.reuters.com/article/2011/01/20/idINIndia-54285820110120) The 2010 McKinsey Global Survey also shows that the external discussion with suppliers is an important source of new ideas for 75% of the 722 surveyed top executives. Suppliers may benefit from assured demand and the chance to develop specialized expertise. Outsourcing product design has helped companies like IBM, HP and Motorola to freeze their R&D budgets by making use of supplier-developed concepts (Koch, 2005). In addition, suppliers may provide information regarding their manufacturing process capability, which should be integrated into product design from the outset to ensure high product manufacturability (Swink 1999).

To realize such benefits, however, distributed project tasks need to be coordinated through inter-firm communication so that interferences could be avoided (Lakemond et al., 2006; Takeishi, 2001; Jayaram, 2008; Ragatz et al. 2002). Without appropriately structuring day-to-day exchange of information between employees from the two firms involved in interdependent activities, interdependent project tasks can not fit together to deliver a good design in a timely fashion (Doz, Hamel and Prahalad, 1989, Sobrero and Schrader 1998). Furthermore, members from the two firms need to agree, to a certain extent, what goals the joint effort needs to achieve (Sivadas and Dwyer, 2000). Goal congruence, the extent to which a buyer and a supplier perceive the possibility of common goal achievement, measures the extent of such agreement (Jap 1999). Literature has shown that both goal congruence (Eisenhardt 1989, Jap 1999, Rossetti and Choi 2008) and inter-organization communication (Ulrich and Eppinger 2000, Sosa et al. 2002, Sobrero and Schrader 1998, etc.) affect performance of inter-organizational collaboration, such as joint NPD projects.

Appropriately structuring inter-firm communication and aligning goals are necessary but not sufficient. Additionally, the manner in which the two firms interact on an on-going basis, i.e. their collaboration quality, is also a key factor to group design efforts (Zeng and Chen 2003, Das and Teng 1998, Kahn 1996, Gomes et al. 2003, etc.).

1.2 Research questions

The manner in which technical information amongst product development members is exchanged significantly predicts NPD projects successes (Allen 1977, Clark and Fujimoto 1991, Wheelwright and Clark 1992, Ulrich and Eppinger 2000, Sosa et al. 2002, 2003, 2004). Specifically, the frequency of information sharing has been found to be positively associated with NPD project performance (Baltontin et al. 1999, Takeishi 2001, Jayaram 2008). Communicating too frequently however may be counterproductive in terms of reducing design efficiency and product quality (Hoegl and Wagner 2005). So how much communication is enough?

On one hand, more communication offers a higher level of information processing capacity for managing interdependent tasks; on the other hand, it consumes more resources due to different levels of structural complexity (Olsen et al. 1995). Literature has suggested that the information capacity offered by coordination mechanisms should match task interdependency levels to generate better task outcomes (Galbraith, 1977; Tushman and Nadler, 1978). When information processing capacity is less than what is necessary to perform the task, performance standards will not be met, the task will not be completed on time, and/or the task will be completed at a higher than desired cost. On the other hand, when the organization employs an approach that provides more information processing capacity than is required, the task will be accomplished in an inefficient manner (Olsen et al. 1995). Therefore there is an *optimal* level of information processing capacity provided by coordination mechanisms within an organization: *not too much and not too less*.

In an inter-organizational context, there are mixed findings regarding the effects of communication intensity on performance. More communication is not always positively associated with performance (Kahn 1996, Hoegl et al. 2004, Hartley et al. 1997, Hoegl et al. 2004, Hoegl and Wagner 2005). However, aligned activities among autonomous units always improve performance (Mohr and Spekman 1994, Hoegl et al. 2004, Hoegl and Weinkauf 2005).

Although over-coordination has been shown to negatively affect organizational performance (Olsen et al. 1995, Andres and Zmud 2002), little is known regarding performance implications of over-coordination, e.g., over-communication, in an inter-organizational context. Two aspects of design performance are studied in the dissertation: design quality and designs efficiency. Design quality is the degree to which the product design met performance goals related to its fitness for use (Swink and Calantone 2004), while design efficiency is defined as the extent to which resources are fully utilized on productive design activities (Hoegl and Gemuenden 2001). Whether benefits of inter-firm communication, in terms of aligning activities, always outweigh costs associated it remains largely unknown in an inter-organizational context. Therefore my first research question within the context of buyer-supplier new product design is:

Is more communication between a buyer group and a supplier group always better for design performance, or is over-communication a risk?

In addition to coordinating interdependent activities through inter-firm communication, goals of the two firms also need to be appropriately aligned to increase commitment and minimize friction (Jap and Anderson 2003, Lakemond et al. 2006). Goal congruence is defined as the extent to which partners perceive a possibility of common goal achievement (Jap 1999). It represents "an assurance that the other party will not pursue activities that are advantageous to its competitive position at the expense of the other" (Jap

1999, pp. 465). Both positive effects of congruent goals (Zeng and Chen 2003, et al.) and negative effects of goal conflicts (Park and Ungson 2001, et al.) have been well studied. A large body of contract management literature has been devoted to studying how to align different goals of supply chain members to improve channel performance, given individual firms' self-serving activities (see Cachon 2004 for a review). Within a single firm, low goal incongruence is shown to be associated with high project performance (Andres and Zmud 2002). In inter-organizational collaboration, goal congruence has been shown to increase coordination efforts spent by buyers and suppliers (Jap 1999, 2001) and is associated with higher relational rents (Dyer and Singh 1998). However, benefits associated with an intermediate level of goal heterogeneity, in terms of maximizing problem solving capability, have also been found(Weick 1979, Thomsen 1998). Thus it is not clear whether inter-firm goal congruence is necessary for improving performance of buyer-supplier joint innovation.

Given the extensive findings on inter-functional goal congruence in single-firm NPD projects (Moenaert et al. 2000, Andres and Zmud 2002, Witt et al. 2001, Hirunyawipada et al. 2009, Pinto et al. 1993, McDonough 2000, Thomsen 1998), it is surprising that inter-firm goal congruence in joint projects has not received more attention in multi-firm NPD literature (Sivadas and Dwyer 2000, Littler and Leverick 1995). Thus my second research question is

Is more goal congruence between a buyer group and a supplier group always better for improving design performance?

Even when appropriate communication and goal structures are established, a design could still be bad if a high-quality inter-firm interaction process does not *emerge*. Collaboration quality, the effectiveness of inter-firm interaction in the collaboration process, is predictive of successful collaboration outcomes (Birou and Fawcett 1994, Gupta and Souder 1998, Hoegl and Wagner 2005, Bonaccorsi and Lipparini 1994, Swink 1999, Jap 1999, Primo and Amundson 2002). By "effectiveness", I mean the extent to which sufficient efforts, mutual support, coordinated activities, accurate and timely communication and balanced contributions are exhibited in the manner in which the two firms interact on an on-going basis (Hackman 1987, Hoegl and Gemuenden 2001).

Collaboration quality has not been as widely studied as communication intensity and goal congruence. Most of the studies on collaboration have focused on individual dimensions of collaboration quality, such as communication quality (Cai et al. 2006, etc.), mutual supports (Bonaccorsi and Lipparini 1994, etc.) and commitments (Walter 2003, etc.). Only a few directly study effects of collaboration quality, as a single comprehensive construct, on performance (Heimeriks and Schreiner 2002, Hoegl and Wagner 2005). Nominal and operational definitions of collaboration quality, however, are not provided in these studies. Thus it is not clear how collaboration quality is different from similar constructs used in the literature, such as *collaboration* (Kahn 1996, Barratt 2003, Jassawalla and Sashittal 1998) and *collaboration capability* (Blomqvist and Levy 2006, Sivadas and Dwyer 2000, Lambe et al. 2002, Kale et al. 2002).

Thus the third research question is:

What are the effects of collaboration quality on design performance?

A final research question regards the relationship among the three independent variables: communication intensity, goal congruence and collaboration quality. There is a lack of empirical studies that examine inter-relationships among the three, especially in the context of supplier involvement in NPD projects. Some of papers study interactions between two of the three constructs. Some focus on causal relationships (Moenaert et al. 2000, Samaddar et al. 2006, Hauptman and Hirji 1999, etc.), while others study moderating relationships (Mohr et al. 1996, etc.). No study has been identified study interactions among the three.

According to Hackman's group effectiveness theory, collaboration quality, as a measure of collaboration process effectiveness, should mediate the effects of communication intensity and goal congruence, two organizational design factors, on design performance. However Hackman's model does not specify the strength of the mediation role. It would be particularly interesting if the mediating effects dominated the main effects, as this would suggest that project success is more dependent on what *emerges* (collaboration quality) than was is *planned* (communication intensity, goal congruence). Thus my fourth research question is:

Does collaboration quality fully or partially mediate the effects of communication intensity and goal congruence on design performance?

1.3 Research context and Unit of Analysis

The unit of analysis is a buyer group-supplier group (BG-SG) dyad working in a NPD project. Each dyad is composed by two groups of people, one group from each firm. The two groups assume different types and levels of design responsibilities. The buyer group may or may not be directly involved in the core design work for a product. I assume however that the buyer group is responsible for ensuring that the product design fits into the whole product and is manufacturable. I assume the supplier group is actively involved in the design job of the product. I make no assumptions about how the product is manufactured—production could be done internally by the buying firm, or outsourced to the same supplying firm who is involved in design, or outsourced to a third-party contractor.

1.4 Methods and analysis summary

An empirical survey of manufacturers in the United States and China was the primary method of data collection. Manufacturers that integrate and assemble complex and discrete products for end consumers are my target population. Two project members from the buying group were asked to choose a recently completed NPD project and answer questions about the project. A sample of 426 projects, with 212 from China and 214 from the United States, was collected.

Design engineers and project managers from manufactures were my target respondents. Common method bias is avoided by separating responses for independent and dependent variables. Both structural equation modeling (SEM) and hierarchical regress were employed to assess statistical significance of the proposed relationships. Measurement invariance was shown using two-group SEM analysis before the United States and China samples were combined. The effects of supplier involvement timing, task relevant expertise, country, sale, firm size and firm age, were controlled for in all the analysis.

1.5 Theoretical and practical contributions

This study has several theoretical contributions. Theoretically, I introduced the concept that there is an optimal level of inter-firm communication intensity, exceeding which lowers design efficiency without improving design quality. It is shown that design performance is best when inter-firm communication intensity is aligned with the uncertainty present in the project; either over- or under-communication can occur and have negative performance implications. Second, this study theoretically defines and empirically operationalizes two types of uncertainty, one on the project level and one on the inter-firm level, which moderate the effects of inter-firm communication and goal structures on collaboration outcomes. Third, adopting a contingency theory's perspective, this study examines the conditions when goal congruence is more effective in improving collaboration outcomes. Fourth, this study nominally and operationally defines collaboration quality, a theoretical construct which measure the effectiveness of inter-partner interactions rather than mere existence or amount of certain activities pursued by partners. Finally, my study proposes several enhancements to existing construct measures.

This study also has several practical implications. First, this study suggests that it is not appropriate to communicate with all the involved suppliers in the same way. Then, buyers are reminded of costs associated with over-communication. Instead of trying to communicate with suppliers as intensively as possible, buyers should communicate with suppliers at the right frequency through the right media to avoid either uncoordinated activities or coordinating activities inefficiently. Third, this study identifies three sources of technical uncertainty, thus offering a more complete view on technical challenges in inter-firm joint product innovation. Fourth, relational uncertainty's significant role in increasing the importance of communication intensity as well as its direct negative impacts on collaboration outcomes provide evidence of project-level benefits of a cooperative buyer-supplier relationship. Fifth, empirical validation of goal congruence's positive effects on process effectiveness, and further onto collaboration performance, supports the importance of inter-firm agreements on project and product targets. Sixth, the negative interaction between goal congruence and technical uncertainty suggests that less emphasis should be placed on goal congruence when selecting suppliers to be involved in manufacturer's NPD projects. Finally this study shows the importance of monitoring the on-going collaboration process.

1.6 Overview of the study

Chapter one provides the introduction and overview of the dissertation. Chapter two consists of a review of the literature on inter-organizational collaboration and new product development. Chapter three outlines the model framework of the study and testable hypotheses. Chapter four provides the research methodology. Chapter five provides a summary of results.. In Chapter six, I discuss theoretical and practical contributions, the limitations and future research extensions.

2 LITERATURE REVIEW

This chapter discusses the topics of communication structure, goal congruence and collaboration quality. Two streams of literature are examined: interorganizational collaboration (IOC) and new product development (NPD). The IOC literature is further categorized into three components: interorganizational collaboration in general, strategic alliances, and buyer supplier collaboration. The NPD literature is further classified into two categories: single firm projects and multiple firm projects. The purpose of this literature review is to see how existing literature can answer my four research questions and where there are gaps.

For each paper, I summarize its main results in four categories according to my four research questions: (1) What effects does the communication structure have on performance? (2) What effects do congruent goals have on performance? (3) What effects do individual dimensions of collaboration quality have on performance? (4) What are the interrelationships among the communication structure, goal congruence and collaboration quality and how do they interact in affecting performance? A summary of what we learn from the literature and where gaps are in the literature is provided at the end of this chapter.

2.1 Communication structure and performance

Taken as a whole, those studies which examined the link between communication structure and performance have mixed findings. Most of studies found that the communication structure (e.g., media, frequency, intensity, direction, etc.) is significantly associated with better performance at different levels (Kumar et al. 1996, Dyer 1997, Takeishi 2001, Mohr and Spekman 1994, et all.). Inter-organizational collaboration literature focuses on performance at inter-organizational network or firm levels, while new product development literature focuses on performance at firms, or project, or product levels. Some studies, however, find that positive effects of the communication structure on performance are contingent on environmental factors, such as task interdependency (Artz and Brush 2000, Cai et al. 2006, Andres and Zmud 2002). Some even find that frequent and intense communication, or simple interactions, do not improve performance (Hartley et al. 1997, Hoegl and Wagner 2005, Kahn 1996).

Studies that support the effectiveness of communication in improving performance can be categorized into two groups. The first group examines the *quantitative* nature of communication, e.g., frequency of information sharing, on performance at different levels. Frequent information sharing reduces transaction costs (Dyer 1997), enables inter-organizational collaboration (Chae et al. 2005), improves purchasing performance (Cai et al. 2006), enhances performance of buyers (Sanders 2007) and suppliers (Petersen et al. 2003), increases project success rates (Baltontin et al. 1999), and improves component design quality (Takeishi 2001, Jayaram 2008).

The second group examines the *qualitative* nature of communication, such as richness of communication media, formality, diversity, centralization, information content, etc. For instance, Antioco et al.(2008) found that communication channels and information content affects the information use of product designers, which ultimately affect design performance. Electronically mediated communication, one type of communication channel, plays a significant role in building collaborative partnership involving standard products (Myhr and Spekman 2005). Face-to-face communication, another type of communication media, is also found to improve design quality when a buyer involves a supplier in NPD projects (Takeishi 2001). When communication is more non-coercive, positive effects of asset specificity on OEM's negotiation costs with suppliers are reduced (Artz and Brush 2000). Cai et al. (2006) shows that diversity, but not formality, of Internet communication is positively associated with purchasing performance. Interestingly, information that is exchanged does not always need to be complete and accurate. Sharing preliminary information is shown to be important for successful coordinating concurrent engineering activities (Terwiesch et al. 2002).

Mixed findings have been identified regarding the performance implications of communication intensity. For instance, it is found that communication frequency and intensity are either not significant predictors of better performance (Kahn 1996, Hoegl et al. 2004, Hartley et al. 1997) or negatively (Hoegl et al. 2004) or curvilinearly (Hoegl and Wagner 2005) associated with performance. The major reason is that when people do not communicate the right content to the right person at the right time, frequent communication can lead to information overload, which divert people from their core tasks, without improving alignment among interrelated tasks (Hoegl and Wagner 2005). Myhr and Spekman (2005) found that information sharing between dealers and manufacturers is negatively associated with dealers' satisfaction with profits. The authors explain this negative link as due to dealers' higher expectation on profits when they are engaged in more intensive communication with manufacturers. It is also possible that information overload reduces the two parties' capability in identifying the most critical information, thus diverting them from productive activities which could generate more profits. None of these studies examine the *fit* between communication intensity and the task environment. In other words, these studies fail to go one step further to explain the failure of intensive communication in improving performance. Specifically, whether there exists an "optimal" level of communication intensity that maximize performance and how this optimal level could be determined are largely unknown.

Among a few studies which adopt the "fit" perspective in examining the optimal coordination structure, Olsen et al. (1995) found that more participative coordination structures work better to improve product development performance when product innovativeness is high. Similar with my dissertation, Olsen et al. (1995) adopts an information processing theory (IPT)'s perspective in examining the best cross-functional coordination structures. Their studies found that the participativeness of the cross-function coordination structure should fit with the newness of the product concept, which is positively associated with resource dependency among functions. Running a lab experiment, Andres and Zmud (2002) found that organic coordination is more effective in improving single-firm software project performance when task interdependency is high and goal conflicts is low. Adopting a social-technical congruence perspective, Cataldo et al. (2008) found that the structure of technical dependencies and software developers' social coordination patterns should fit in order to maximize software development productivity. However, projects examined in these studies do not consider projects that involve members from different organizations.

In an inter-organizational context, Stock and Tatikonda (2008), adopting the IPT perspective, found that the match between task (external technology integration) uncertainty and inter-organizational interaction (effective communication, high degree of coordination and cooperative attitudes) leads to higher technology integration performance. It is found that inter-organizational interaction could be "too much". If the external technology that is to be integrated is well understood by the recipient, inter-organizational interaction is counterproductive to project success. However, the quantitative (frequency and intensity of the coordination) and qualitative (effective communication and cooperative relationship) characteristics of inter-firm interactions are subsumed under one construct "inter-organizational interaction". Thus there is no way to test their individual effects on project outcomes.

All the above "fit" studies only consider the role of technical characteristics of the task in selecting an appropriate coordination structure. The potential role of relational factors among project members, such as familiarity, trust, etc., in affecting coordination effectiveness is largely ignored. The only study that examined the moderating roles of both technical and relational sources of uncertainty in inter-organizational interactions is Manil et al. (2007). Their analysis of 137 business process outsourcing projects reveal that contractual coordination should fit with relational uncertainty, while procedural coordination should fit with process uncertainty, for successfully outsourcing business processes. Relational uncertainty is defined as the uncertainty perceived by the user firm about its relationship with the service provider, while process uncertainty is the uncertainty in execution and management of the outsourced process across organizational boundaries. In summary, the review above shows that intensive communication does not always improve performance--contingency factors that enhance/lower the importance of inter-firm communication exist. . For instance, in a case study of six buyer-supplier joint NPD projects, Lakemond et al. (2006) proposed that higher task dependence, diverging expectations and a long-term learning orientation all make intensive inter-firm communication more important My study adopts a contingency perspective. I try to identify the *optimal* level of communication intensity, given the level of technical and relational uncertainty, as well as performance implications of both over- and under-communication.

2.2 Goal congruence and performance

Taken as a whole, literature reviewed generally support the notion that goal congruence among collaborating units positively contributes to the performance of these units. Some of the studies examine the positive effects of goal congruence (Zeng and Chen 2003.), while some others identify negative effects of goal conflict (Park and Ungson 2001, et al.). There are also some papers, instead of directly studying goal congruence, that focus on mechanisms that could help cultivate aligned objectives (Cai et al. 2009, et al.). However, it has also found that a moderate level of differences in goals can improve problem solving quality in groups (Thomsen 1998).

A major benefit of aligning goals among units working together is to improve productivity by channeling members' efforts in a singular direction. On an inter-organizational level, it is shown that goal congruence among partners promotes cooperation in alliances (Zeng and Chen 2003, Chae et al. 2005) and increases the coordination efforts spent by firms (Jap 1999, 2001). When a buyer collaborated with a supplier in NPD projects, a shared vision (Sivadas and Dwyer 2000) and inter-firm agreement on objectives (Littler and Leverick 1995) improves cooperative competency among partners, which ultimately increases project performance. Within a project team, goal congruence among members is found to enhance expectation and improves communication in international product development teams (Moenaert et al. 2000). Low goal conflicts are found to be associated with higher product performance in NPD projects (Andres and Zmud 2002). Shared priorities enhance the single-minded direction that a team is moving toward (Witt et al. 2001). Goal congruence within a cross-functional team also helps transform tacit knowledge owned by individual team members into collective knowledge shared by everyone in the team (Hirunyawipada et al. 2009). Super-ordinate goals shared by members in a cross-functional team promote cross-functional cooperation, which ultimately improves project outcomes (Pinto et al. 1993, McDonough 2000). Without sharing the same goal, product development performance can not be improved even if different functions meet and share information with each other regularly (Kahn 1996, Gomes et al. 2003).

Goal conflict/incongruence increases "friction" costs among partners. Inter-firm rivalry is a major reason for alliance failures (Park and Ungson 2001). In a buyer-supplier dyad, self-serving behaviors could amplify the positive effects of asset specificity on OEM's negation costs with a supplier, in addition to its direct positive effects on negation costs (Artz and Brush 2000). In single-firm NPD projects, Thomsen (1998) found that goal incongruence reduces coordination quality and decision-making quality due to the "friction". When a buyer collaborates with a supplier in NPD projects, diverging expectations drives them to spend more efforts in coordination, which diverts them from core design work and reduces productivity (Lakemond et al. 2006). The intensity of buyer-supplier conflict in NPD projects is found to be negatively associated with project performance (Lam et al. 2007).

Some other studies examine mechanisms that could help with aligning goals among partners. For instance, joint planning, one mechanism that could help a buyer and a supplier reach agreements in advance, is found to be positively associated with the supplier firm's performance (Cai et al. 2009). In buyer-supplier collaborative NPD projects, formalized risk/reward sharing agreement and joint agreement on performance measures significantly contribute to successful supplier integration (Ragatz et al. 1997).

It is also possible, however, that a medium level of goal heterogeneity improves group performance. Thomsen (1998), using a computational model of project teams, found that a medium level of differences in ranking among multiple goals by group members actually maximizes problem solving quality and minimizes project costs and duration. Low levels of such differences in prioritizing multiple goals will cause the adoption of weaker solution due to the lack of diversity (Weick 1979). Thomsen (1998) proposes that differences in goals "can increase the diversity of behavioral repertoires available to the project to meet the requirements imposed by the environment" (pp. 81). Thus lower project costs and shorter duration could be achieved.

Such performance-improving potential of goal conflicts are consistent with several recent studies examining the "dark side" of repeated collaboration. When partners collaborate for a long time, they tend to develop such a high level of congruence in goals, opinions, and processes that they won't challenge each other's proposals and thus are less likely to come up with innovative solutions. For instance, Skilton and Dooley (2010) proposed that team mental models developed in earlier collaboration are likely to interfere with the process of creative abrasion (Leonard and Swap, 1999). Specifically, they discuss how the processes of idea generation, disclosure/advocacy, and convergence can be suppressed by team-level mental models, which in turn leads to less creative outcomes.

Similarly, Bidult and Castello (2010) found that companies who have a long collaboration history tend to trust each other "too much". In other words, they do not doubt whatever the partner proposes. A lack of conflicting opinions among collaborating firms, however, leads to less innovative solutions.

In sum, most of the literature in inter-organizational collaboration and NPD proposes that congruent goals among autonomous parties who work together tends to improve the performance of the collective output. For NPD projects within a single firm, goal congruence/conflicts among different functions have been extensively studied. However, some innovation and team management researches do find that a certain level of goal incongruence may improve innovation performance through increasing decision quality (Bidult and Castello 2010, Chen et al. 2008, De Dreu 2006). Finally, there is a lack of empirical studies that directly examine effects of goal congruence on collaborative innovation project performance. Specifically, whether goal congruence could be "too much" and when it is most effective in improving supply chain collaboration performance are largely unknown. This is surprising because goal conflicts exist not only among different professions, but also among different firms. My study attempts to fill this gap.

2.3 Collaboration quality and performance

Collaboration quality measures the extent to which members interact with each other in an effective way. According to Hackman's criteria for group process effectiveness (Hackman 1987, Campion et al. 1993), team management literature (Hoegl and Gemuenden 2001), and the collaboration literature (Gray 1985, 1989, Wood and Gray 1991, Amabile et al. 2001, Jassawalla and Sashittal 1998, Tjosvold 1984, 1995), there are five dimensions of collaboration quality: communication quality, mutual support, sufficiency of efforts, coordination and knowledge/skill-based contributions. Thus the effectiveness of a collaboration process is indicated by high quality communication, mutual support, sufficient efforts, coordinated tasks and knowledge/skill-based contributions. The section will be organized around these dimensions.

Communication quality measures the extent to which communication is timely and accurate. Mutual support measures the extent to which autonomous units openly share important ideas and adapts well to each other in a cooperative atmosphere. Sufficiency of efforts measures the extent to which all units are fully committed to reaching shared goals of the collaboration. Coordination measures the extent to which dependencies among individual efforts are effectively managed (Espinosa et al. 2002). Knowledge/skill-based contributions measure the extent to which no one is limited in applying knowledge/skill to the collaborative task.

Communication quality has been shown to improve performance on different levels. Inter-organizationally, collaborative communication positively affects suppliers' performance and enhances buyers' commitment to the relationship (Cai et al. 2009). Communication quality between dealers and manufacturers is found to be positively associated with dealers' satisfaction with manufacturer's supports (Mohr and Spekman 1994). Cross-functionally, high quality information sharing leads to high financial performance of projects (Yap and Souder 1994). Within a project team, completeness of information exchanged is positively associated with both technical and commercial successes (Souder and Chakrabarti 1978).

There is a general support on the positive effects of mutual supports among partners on outcomes of their collaborative work. In a buyer-supplier dyad, Bonaccorsi and Lipparini (1994) is one of the few who directly examine effects of mutual supports. They found that mutual support between the manufacturer and its suppliers are critical for NPD success. A lack of mutual supports, indicated by supplier's obstructionism, is shown to be negatively associated with project development time (Primo and Amundson 2002). Responsiveness to the other partner' needs is found to be critical for a successful buyer-supplier relationship (McCutcheon et al. 1997). When partners mutually support each other in face of changes and conflicts, they will take other partner's needs into consideration. Lam et al. (2007) found that both integrating and obliging conflict management styles, where buyers are concerned with suppliers' needs, are positively associated with NPD performance. Thus their finding indirectly supports the positive effect of mutual supports on project performance. Within a project, Swink (1999) found that a mutually supporting environment, where different functional specialists work together, contributes to new product manufacturability.

Enough efforts need to be applied to the joint task to ensure a successful collaboration. In a general buyer-supplier dyad, Walter (2003) showed that suppliers' commitment is positively associated with the extent of supplier involvement in NPD projects initiated by buyers. Specifically, in a dealer-manufacturer dyad, dealers' commitment to manufacturers is positively associated with their satisfaction with manufacturer's supports and dyadic sales (Mohr and Spekman 1994). Similarly, in a new venture-supplier dyad, new venture's commitment to a supplier drives higher extent of supplier involvement in NPD projects, which ultimately improves project performance (Song and Benedetto 2008). In a cross-functional team, commitment to projects by all the members is rated as one of the most important success factors for NPD projects (McDonough 2000). Commitment, sometimes, works as a moderator, strengthening positive roles played by other factors on project performance. For instance, Mabert et al. (1992) found that the advantages of supplier early involvement were seen as high if the buyer signed a firm commitment with the supplier.

Thus coordination of joint activities among autonomous units has been shown to improve collaboration performance. On an inter-organizational level, coordinated activities between dealers and manufacturers are significantly associated with dealers' satisfaction with manufacturers' supports and dyadic sales (Mohr and Spekman 1994). On an inter-functional level, coordinated activities among marketing, engineering and manufacturing have been widely shown to be associated with NPD project successes (Ziger and Maidique 1990, Song et al. 1998, Sherman et al. 2005, Ragatz et al. 2002, et al.). The positive effects of cross-functional coordination on performance, however, are contingent on specific performance measures used (Hoegl et al. 2004), project and product characteristics (Fredriksson 2006, Swink et al. 1996), and project phases and function types (Song et al. 1998). On an inter-team level, alignment of interdependent tasks conducted by autonomous teams is associated with better schedule-conformance performance of individual teams in complex product development projects (Hoegl et al. 2004, Hoegl and Weinkauf 2005).

Knowledge/skill-based contributions have not received enough attention in either inter-organizational collaboration or NPD literature. Hoegl and Gemuenen (2001) proposed a theoretical construct, teamwork quality, which measures the collaboration level within a team. Knowledge/skill-based contribution (called balance of member contributions in the paper) is one of the six dimensions of teamwork quality. Then Hoegl et al. (2004) found that teamwork quality is positively associated with overall NPD team performance and adherence to schedules, but not with quality and adherence to budgets. Teamwork quality is more important in early, than in later, stages of the NPD project. .

There are a few studies, instead of studying individual dimensions of collaboration quality, examine it as a single construct, though defined differently across studies. In their conceptual paper, Heimeriks and Schreiner (2002) defined collaboration quality as specificities of alliance characteristics which have significant positive effects on alliance performance. Specifically, collaboration quality is a synthesis of six dimensions: (1) resource configuration, (2) compatibility of partners, (3) coordination features, (4) level of trust, (5) level of commitment and (6) level of information sharing and communication. It is proposed that collaboration quality mediates the positive effects of alliance capability onto alliance performance. Collaboration quality defined in their study is different from the one in my dissertation, which focuses on the effectiveness of inter-firm interaction during the joint project. For instance, some dimensions discussed in Heimeriks and Schreiner (2002), such as resource configuration and compatibility of partners, are concerned more with partner selection before the alliance is formed, rather than how well partners interact with each other during the alliance. Furthermore, the communication dimension fails to differentiate the level of communication (e.g., frequency and intensity) from the quality of communication (e.g., timeliness and accuracy) in their study.

Hoegl and Gemuenden (2001) studied the quality of teamwork, a specific type of collaboration, and its impacts on team performance. Teamwork quality (TWQ), a measure of the collaboration level within a team, is shown to be positively associated with team performance and is more important in early stages of a project. Specifically, TWQ is composed by six dimensions: communication, coordination, balance of member contributions, mutual support, effort, and cohesion. Most of the dimensions underlying apply to a buyer-supplier collaborative innovation context, except the cohesion dimension, which refers to the degree to which team members desire to remain on a team. The reason is that when members from two firms work together on a project, they do not necessarily need to physically form (or at least perceive that they belong to) a team to complete the task. Different forms of supplier involvement into manufactures' NPD projects have been observed (Ragatz et al. 2002). For instance, a buyer firm could simply consult suppliers for design ideas (the white-box supplier integration), or work jointly with a supplier (the grey-box), or allow a supplier to complete a part of the design on its own (the black-box) (Petersen et al. 2005). Thus members from the two firms do not need to perceive that they belong to a single team and further want to remain in the team (high cohesion) in order to collaborate well.

The buyer-supplier collaboration construct in Hoegl and Wagner (2005) is most similar to the one used in my dissertation. Their study extended the concept of teamwork quality to a buyer-supplier collaboration context. The authors used buyer-supplier collaboration to measure the "qualitative" nature of supplier involvement in buyers' NPD projects, which is differentiated from the "quantitative" aspects (e.g., frequency of communication, etc.). They found that collaboration quality is positively associated with NPD project performance, after controlling for the curvilinear effects of communication intensity and frequency. However they did not give a nominal definition for buyer-supplier collaboration. Furthermore, their buyer-supplier collaboration construct does not involve two important dimensions: sufficiency of efforts and coordination of interdependent activities.

In summary, compared with communication structure and goal congruence, collaboration quality has not been as widely and intensively studied in inter-organizational collaboration and NPD literature. Most of the studies focus on individual dimensions, such as communication quality, mutual supports, sufficiency of efforts, coordination, and knowledge/skill-based contributions, of collaboration process effectiveness. A few directly study effects of collaboration quality on performance, however, without offering consistent nominal and/or operational definitions. My dissertation, following this last group of studies, attempts to examine effects of collaboration quality on project performance from a group effectiveness perspective.

2.4 The interactions among communication structure, goal congruence and collaboration quality

Among all the papers reviewed in this chapter, only a few study the interrelationships among communication structure, goal congruence and collaboration process effectiveness. They could be further categorized into two groups. The first group examines the causal relationships among the three. The second group studies one construct as a moderator to the causal relationship between another construct and performance.

Studies in the first group have identified causal relationships between any two pairs of the three constructs. Between goal congruence and collaboration quality, Moenaert et al.

(2000) found that goal congruence enhances communication effectiveness and efficiency in NPD projects. Between goal congruence and communication structure, Samaddar et al. (2006) found that buyer-supplier goal congruence increases the strategic nature of inter-organizational information sharing they engage in. Between communication structure and collaboration quality, Hauptman and Hirji (1999) found that IT-mediated communication contributes to an effective team process in concurrent engineering. Olsen (1995), in studying NPD projects involving cross-functional teams, found that participative communication and decision making are likely to improve the effectiveness and timeliness of the product development process when the product being developed is truly new and innovative. Mohr et al. (1996), in studying vertical inter-firm relationship, found that collaborative communication increases channel members' satisfaction, commitment and coordination. Goke and Idiaborn-Goke (2010), studying innovation-driven horizontal networks, found that communication channel richness is positively associated with social tie strength among network members. Only one study examines the interaction effect, the one between the communication structure and collaborative process effectiveness. Chae et al. (2005) found that cooperative and close relationships augment the positive effect of IT on inter-organizational collaboration.

In sum, there is a lack of empirical studies that examine inter-relationships among communication structure, goal congruence and collaboration quality, especially among studies examining supplier involvement in NPD projects. Some of the few that did so focus on the causal relationships among the three, while the remaining ones focus on the moderating relationships between communication structure and collaboration quality. My dissertation attempts study the causal relationships among the three by extending Hackman's work group effectiveness theory to an inter-organizational context. Specifically, I propose a mediating role played by collaboration quality, which transforms the effects of communication intensity and goal congruence on project outcomes.

2.5 Chapter summary: gaps in the literature and my contributions

Taken as a whole, the literature reviewed above shows us that communication structure, goal congruence and collaboration quality are closely related with performance at different levels. There are several gaps in the literature, however.

First, it is not clear how the inter-unit communication should be structured to improve collaboration performance in a most efficient and effective way. Second, effects of goal congruence between two groups, each from a different firm, on NPD project performance have never been examined. Third, effectiveness of the inter-firm collaboration process has not been conceptually defined. Its effects on project performance have not been examined either. Fourth, the interrelationships among communication structure, goal congruence and collaboration quality have not been studied in an inter-organizational collaborative NPD context. Finally, measurements for collaboration quality are not consistent across studies.

With this study I contribute to the literature by studying the causal effects of communication intensity and goal congruence on collaboration quality. Specifically I introduced the concept that there is an optimal level of inter-firm communication intensity, exceeding which lowers design efficiency without improving design quality. Instead of focusing on characteristics of individual firms, I propose that the *match* between two firms in both actions and goals is an important project success factor. Such a match increases the effectiveness of the collaboration process, or collaboration quality, a theoretical construct whose nominal definitions and operational dimensions are offered for the first time. To study the interrelationship among communication intensity, goal congruence and collaboration quality, I extend Hackman's work group effectiveness theory to an inter-organizational context. Finally, my study proposes several enhancements to existing construct measures.

Table 2-1 Literature review on communication structure, goal congruence and collaboration quality

		Recent notable manuscripts	Communication Structure	Goal congruence	Collaboration quality	Interactions
Interorganizational collaboration	Strategic alliance in general	Kumar and Van Dissel (1996)	Technical and procedural coordination reduces technological and economic risks in inter-organizational systems			
		Heimeriks and Schreiner (2002)			Collaboration quality is both an intermediate outcome of alliance capability and is positively related with alliance performance.	
		Zeng and Chen (2003)	Enhancing communication contributes to alliance partner cooperation.	Long-term goals shared by partners promote cooperation in alliances.		
		Park and Ungson (2001)		Inter-firm rivalry is a major reason for alliance failure.		
		Bidult and Castello (2010)		Conflicting opinions about tasks can spur new solutions, thus increasing innovation performance		
		Oke and Idiaborn-Oke (2010)	Communication media richness is negatively associated with NPD development time in innovation-driven horizontal networks			Communication media richness is positively associated with tie strength in a horizontal NPD collaboration network
	Buyer-supplier collaboration	Cai et al. (2009)		Joint planning positively affect suppliers' performance	Collaborative communication positively affects the supplier's performance and enhances the buyer's commitment to the relationship.	
		Dyer (1997)	Extensive information sharing reduces the transaction costs and promotes investment in			

	relation-specific or co-specialized assets.			
Mohr and Spekman (1994)	Information sharing is negatively associated with dealer's satisfaction with profits.		Dealers' commitment to manufacturers is positively associated with their satisfaction with mftr's supports and dyadic sales. Communication quality is positively associated with dealers' satisfaction with mftr's supports.	
Myhr and Spekman (2005)	Electronically mediated communication, compared with trust, plays a larger role in building collaborative partnership involving standardized products.			
Mohr et al. (1996)				Collaborative communication increases channel member commitment and coordination
Artz and Brush (2000)	Usage of non-coercive communication reduces the positive effect of asset specificity on OEM's negotiation costs with a supplier, in addition to its direct, negative effect on negotiation cost.	Discouraging self-serving behaviors reduces the positive effect of asset specificity on OEM's negotiation costs with a supplier, in addition to its direct, negative effect on negotiation cost.		
Jap (1999, 2001)		Goal congruence increased the coordination effort spent by a buyer and a supplier		
Scott (2000)	Information technology facilitates inter-organizational learning.			
Chae et al.	Inter-organizatinal information	Long-term orientation contributes to		Cooperative and close

		(2005)	sharing enables inter-organizational collaboration.	inter-organizational collaboration.		relationships augment the positive effect of IT on inter-organizational collaboration.
		Paulraj et al. 2008	Inter-organizational communication serves as a mediator transmitting benefits of long-term relationship orientation, network governance and information technology on buyer and supplier' performance.			
		Cai et al. (2006)	The frequency, diversity and formality of Internet communication significantly affect purchasing performance			
		Samaddar et al. (2006)				Buyer-supplier goal congruence increases the strategic nature of inter-organizational information sharing they engage in.
		Sanders (2007)	Real-time information sharing with a supplier improves the buying firm' organizational performance.			
New product development	Single firm	Moenaert et al. (2000)		Goal congruence enhances expectation and improves communication in the international product development teams.		Goal congruence enhances communication effectiveness and efficiency in NPD projects.
		Witt et al. (2001)		Shared priorities enhance the single-minded direction that a team is moving toward		
		Andres and Zmud (2002)	Organic coordination is more productive than mechanic coordination in software development projects, an effect	Low goal conflict is associated with higher project performance.		

	which is strengthened by task interdependency.			
Souder and Chakrabarti (1978)			Completeness of information exchanged during project work is positively associated with both technical and commercial successes.	
Yap and Souder (1994)			High quality interdepartmental communication is associated with high financial performance of the project.	
Hauptman and Hirji (1999)				IT contributes to an effective team process in concurrent engineering.
Kahn (1996)	More interdepartmental interactions in terms of more meetings and other formal information flows are not significantly associated with better product development performance.	Interdepartmental collaboration, in terms of working collectively towards the common goals, has a strong and positive effect on product development performance.		
Gomes et al. (2003)		Collaboration plays a greater role in enhancing NPD project performance, when compared with interaction.		
Balbontin et al. (1999)	High level of information flow/contact between technical and commercial entities is associated with project success.			
Olsen et al. (1995)	Organic coordination mechanisms should match with more innovative products, while mechanistic coordination mechanisms should match with less innovative product, to			More participative coordination structures are likely to improve the effectiveness and timeliness of the product development process when the product being developed is truly new and

	produce high product development.			innovative.
Thomsen (1998)		Goal incongruence reduces coordination quality and decision-making quality. A moderate level of goal incongruence maximizes problem solving quality.		
Hirunyawipada et al. (2009)		The more a cross functional team achieves goal congruence, the more likely tacit knowledge is transformed into collective knowledge.		
Terwiesch et al. (2002)	Exchange of preliminary information is important for successful coordinating concurrent engineering activities.			
Hoegl et al. (2004)	Interteam coordination is negatively associated with team's adherence to budgets and is positively associated with adherence to schedules in complex products development projects. Quality is not affected significantly by interteam coordination.		Teamwork quality is positively associated with overall team performance and adherence to schedules, but not with quality and adherence to budgets, in NPD projects Teamwork quality is more important in early, than in later, stages of the project. .	
Hoegl and Weinkauf (2005)	Team interface management (direct lateral coordination) reduces schedule slippage in the concept stage.			

	Antioco et al. (2008)	Communication channels and information content affect the information use of product designers			
	Jassawalla and Sashittal (1998)			Cross functional collaboration goes beyond integration and improve performance.	
	Ziger and Maidique (1990)	Cross-functional coordination among marketing, engineering and manufacturing is positively associated with NPD projects successes.			
	Pinto et al. (1993)		Superordinate goals shared by members in a cross-functional team promotes cross-functional cooperation, which ultimately improves project outcomes.		
	McDonough, (2000)		Appropriate project goals shared by all the members in cross-functional teams contribute to project successes.	Commitment to projects and cooperation in cross-functional teams contribute to project successes.	
buyer supplier collaboration in NPD	Hoegl and Wagner (2005)	Communication frequency and intensity have a curvilinear relationship with project development cost and product cost.		Higher buyer-supplier collaboration quality improves new product development projects performance.	
	Sivadas and Dwyer (2000)		A shared vision and values improves cooperative competency among partners.		
	Bonaccorsi and Lipparini (1994)			Mutual support and continuity and stability of the relationships between the manufacturer and the supplier are critical for NPD success.	

Song and Benedetto (2008)			The new venture's commitment to the supplier is positively associated with supplier involvement.	
Primo and Amundson (2002)			Supplier obstructionism, characterized by lack of priority and cooperation, is negatively associated with project development time.	
Walter (2003)			Supplier commitment is positively associated with the extent of supplier involvement in NPD projects.	
Lakemond et al. (2006)	Degree of task dependence drives more extensive buyer-supplier coordination.	Degree of diverging expectations drives more extensive buyer-suplier coordination.		
Lam et al. (2007)		Buyer-supplier conflict intensity is negatively associated with NPD performance.	Both integrating and obliging conflict management styles, where the buyer is concerned with the supplier's needs, are positively associated with NPD performance.	
Takeishi (2001)	Frequent face-to-face communications between an automaker and a supplier leads to higher component design quality.			
Jayaram (2008)	The communication and information sharing dimension of supplier integration is positively associated with design quality and is negatively associated with time-to-market.			
Ragatz et al. (2002)	Cost information sharing and direct cross-functional/inter-firm communication are positively associated with cycle time, quality and cost			

	performance.			
Sobrero and Roberts (2002)	Information transferring mechanisms are significant predictors of relational outcomes in terms of efficiency and learning.			
Swink (1999)			A collaborative work environment contributes to new product manufacturability.	
Hartley et al. (1997)	Communication frequency between the buyer and the supplier is not significantly related with the perception of an increased contribution by the supplier.			
Petersen et al. (2003)	Increased information sharing are needed to improve supplier involvement and to achieve NPD goals.			
McCutcheon et al. (1997)			Responsiveness, cooperativeness, and customer service are critical to the success of the supplier/buyer relationship.	
Mabert et al.(1992)			The advantages of supplier early involvement were seen as high if the buyer signed a firm commitment with the supplier.	
Littler and Leverick (1995)		The success of collaborative product development efforts is achieved when clear parameters of the relationship		

				and objectives are agreed to in advance.		
		Ragatz et al. (1997)		Formalized risk/reward sharing agreements and joint agreement on performance measures contribute to successful supplier integration in NPD projects.		

3 THE THEORETICAL MODEL AND HYPOTHESES

3.1 Research scope and key concepts

To find out whether and when intensive communication and congruent goals contribute to design performance in a manufacturer-supplier joint NPD project, I proposed two theoretical models. The first model, a moderating model, proposes that two types of uncertainty moderate the effectiveness of communication intensity and goal congruence. The second model, a mediating model, proposes a mediating process which transforms the benefits of intensive communication and congruent goals into project outcomes. The two models share one theme: intensive communication and congruent goals are not always effective in improving design performance. Specifically, the moderating model proposes that the strength of the relationship varies with the levels of technical and relational uncertainty, while the mediating model proposes that the relationship exists because of the mediating consequence of collaboration quality. Thus the two models together offer a more complete view on effects of inter-firm communication and goals on collaboration outcomes.

Below I will define three key concepts to specify the scope of the two theoretical models.

A NPD project. In this study, a project is defined as a manufacturer-initiated undertaking for developing a new physical product, where a single supplier is involved in the majority of value-added activity in the design process. Thus the outcomes of a project primarily are due to the efforts of the single buyer-supplier dyad. For example, if two suppliers are involved in the design of an automobile door, one working on the electronic control part and one working on the body design part, then I would model that scenario as two projects, one for each part involving only one supplier. Thus each project suggests one buyer group-supplier group (BG-SG) dyad, which is the unit of analysis in this study.

Multiple dyads, each of which works on a different component, may share one common supplier.

A work group. Following Hackman and Wageman (2005), I define a work group as a set of people who (1) can be distinguished reliably from nonmembers, (2) are interdependent for some common purposes, (3) invariably develop specialized roles within the group, (4) have one or more group tasks to perform, and (5) operate in a social system context. In a NPD project, a work group is composed of engineers and other professionals from both firms. According to Hackman's definition, this set of people can be distinguished reliably from other people in the project due to their common task of developing the new product. Each engineer has specialized roles within the group and is interdependent on each other in performing individual tasks. They, as a collective, operate in the larger social system consisting of the manufacture and supplier firms. What is unique about a work group studied in my dissertation is there are two sub-groups, one sub-group representing the buying firm's participants and one sub-group representing the supplier firm's participants. The two sub-groups are interdependent on each other to deliver a product design that (1) fits into the overall product architecture, (2) fits with target customers' requirements, (3) is manufacturable, and (4) consumes the least amount of time and cost in the design process.

Design performance. I consider two dimensions of design performance, capturing both effectiveness and efficiency of a NPD project. The first one is product design quality, which measures the degree to which the product design met performance goals related to its fitness for use (Swink and Calantone 2004). There are five dimensions: dimensional integrity, durability, functionality, manufacturability (Swink 1999), and fit with target customers' needs. The second type, design efficiency, focuses on the efficiency of the design process, which measures the extent to which resources are fully utilized on productive design activities (Hoegl and Gemuenden 2001). Two types of resources are considered, money and time.

Thus the two dimensions of design efficiency are development cost and time. Figure 3-1 shows the research context and scope.

INSERT FIGURE 3-1 HERE.

Table 3-1 shows nominal definitions and operational dimensions of all the constructs in the conceptual model.

INSERT TABLE 3-1 HERE.

3.2 The moderating model: Technical and Relational Uncertainty

3.2.1 Technical uncertainty: three sources

Galbraith (1973) defines task uncertainty as "the difference between the amount of information required to perform the task and the amount of information already possessed by the organization". Building upon this definition, I define technical uncertainty, in a manufacturer-supplier collaborative NPD context, as the total task uncertainty faced by project members from the two firms while developing the product. There are three sources that contribute to the technical uncertainty: inter-firm task interdependency, technological novelty and product complexity.

Task interdependency. The two sub-groups are interdependent on each other to deliver a design that (1) fits with designs of interrelated products that share interfaces with the product that is designed by the buyer-supplier work group, (2) fits with target customers' requirements, (3) is easily manufacturable, while consuming the least amount of time and cost in the design process. Three sources of task interdependence are discussed below and shown in Figure 3-2.

INSERT FIGURE 3-2 HERE.

The first source is component-product interdependence. This source of interdependency is relevant when the product developed by the buyer-supplier work group is a component of the final product. For instance, an engine developed by a work group is a component embedded in the car, the final product. Then two sub-groups are interdependent due to the dependence between a component design and the overall product architecture. For instance, the design of an engine is interdependent with the overall architecture of the CCS (climate control system) on its interface with auxiliary heaters. The engine and auxiliary heaters should provide a constant total amount of warm water to the CCS system (Terwiesch et al. 2002). The buyer, acting as the system integrator, is always responsible for integrating individual component designs into the overall product architecture (Parker and Anderson 2002). The supplier group may be responsible for a part or all of the design work for individual components. Thus the supplier group depends on the buyer group for accessing product architecture information to deliver a design that does not interfere with other interrelated component designs in the final product.

The second source is within-product design-design interdependence. The two sub-groups are interdependent due to the way the total project task is decomposed between them. When two sub-systems of the product designed separately by the two sub-groups share strong design interfaces, one group's design activities significantly affect design outcomes of the other group. In this case, the two sub-groups need to exchange design information in an on-going way to avoid design interferences within the focal component.

The third source is design-manufacturing interdependence. When a design is "thrown over the wall" to manufacturing without integrating production capability and limitations early into design considerations, the result is often a design that is not easily producible (Adler 1995). The sequential dependency relationship between design and manufacturing makes it necessary to integrate the two sets of information early in the design process (Swink and Calantone 2004).

Because the two sub-groups have different levels of access to design and manufacturing information, they are interdependent on each other in obtaining information they need. On one hand, depending on who does the production for the product, the two sub-groups have access to *manufacturing process information* to different extents. When production of the product is done either by the buyer, the buyer has full access to manufacturing process information. When a third-party manufacturer does the production, it is still the buyer, although to a less extent, that has access to manufacturing capability and constraints information. When the same supplier does both design and production, the supplier has full access to manufacturing process information. On the other hand, depending on design task decomposition between the two sub-groups, they also have different levels of access to product design information. As long as design and production of a component are not done 100% within the same supplying firm, the two sub-groups are interdependent on each other for access to information held *only* by the other sub-group.

Technological novelty. Product development projects vary in their level of technological novelty, which is another major source of uncertainty in NPD projects (Tatikonda and Montoya-Weiss 2001). Novel technologies are those that are new to the development organization. Therefore, at the beginning of a NPD project that employs novel technologies, project members usually do not understand the technology, do not know the exact means of how to proceed, and may not be sure of the desired project outcomes. This lack of knowledge about non-routine technology as well as about the means to accomplish the project contributes to the total uncertainty in the project. A lot of empirical studies have found that NPD projects using novel technology are often less likely to succeed due to their higher uncertainty level (Tatikonda and Rosenthal 2000, Griffin 1997, Clark and Fujimoto 1991, McDonough 1993). For these more uncertain projects to succeed, more coordination is often required. In its study of 45 NPD projects from 12 firms, Olsen et al. (1995) found that more decentralized and participative cross-functional interactions, which offer higher information processing capacity, are needed to improve NPD project performance when the product being developed is truly new and innovative.

Both product and process technologies could be novel. A novel product technology may consist of new product parts, modules, or even architecture, while a novel process technology could consist of new manufacturing tools, process stages, flows or layouts. Although there are mixed findings regarding which type of novelty is more likely to lower project performance, the NPD literature, in general, support that both product and process technology novelty are likely to increase development time and costs (Meyer and Utterback 1995, Clark and Fujimoto 1991). Therefore, both product and process technology novelty is measured in this study to get an overall novelty level.

Product complexity. Product complexity has been shown to be another source of uncertainty in NPD projects. High product complexity causes equivocality, the existence of multiple and conflicting interpretations about the task situation (Koufteros et al. 2002). More specifically, when the product being developed has a large number of components, each of which shares many interfaces with others and requires highly differentiated expertise to develop, it is more difficult for project members to determine what is the right way to design and what might be the effects of their decisions. Therefore, designing a complex product often requires a much higher level of coordination among autonomous units to manage the interdependence (Novak and Eppinger 2001). Past research has shown that projects that develop more complex products often take longer time to complete (Carbonell and Rodriguez 2006, Griffin 1997, Murrmann 1994). Weingart (1992) found that task complexity affects group performance through the amount of planning performed and the level of effort invested. Task complexity, however, is also found, in some cases, to improve work group performance through motivating members to work harder (Campbell and Gingrich 1986, Campion, Medsker and Higgs 1993, Jehn, Northcraft and Neale 1999) and through improving group cohesiveness (Man and Lam 2003). Task complexity also could serve as a moderator strengthening effects of performance enhancers. For example, it amplifies performance benefits of group diversity on group effectiveness (Bowers et al. 2000, Wegge et al. 2008) and participation in goal setting on member satisfaction and motivation (Schnake et al. 1984).

Complexity can arise from the number of subsystems, the level of differentiation among subsystems, and how subsystems are linked together (Dooley and Van de Ven 1999, Dooley 2001). In short, complexity "appears to refer to the load on the system that requires coordination—the higher the differentiation and the loose coupling among the elements in the system, the higher the load required to coordinate the system" (Choi and Hong 2002). Adopting a complexity science's perspective, I operationalize product complexity in three dimensions: (1) the number of product components being designed and produced, (2) the level of expertise required for the design of the new product and how differentiated that expertise is, and (3) the extent of interactions required to effectively manage the interface between these components (parts coupling).

3.2.2 Relational uncertainty

In a manufacturer-supplier collaborative NPD context, relational uncertainty is defined as the difference between the information that members from one firm need and the information that they have in anticipating actions of members from the other firm. Two factors that affect this information gap are: shared cognition and opportunistic behaviors. Specifically, shared cognition reduces the information gap, while opportunistic behaviors increase it.

It is easier to predict actions of members from the other firm when people from the two firms have a shared cognition. Such shared cognition is built upon the shared knowledge members have about the joint task and about each other. "This shared knowledge helps team members understand what is going on with the task, and also helps them anticipate what is going to happen next, and which actions team members are likely to take, thus helping them become more coordinated" (Espinosa et al. 2002). It also facilitates a common understanding of collective goals and proper ways of acting when people from the two firms work on joint tasks (Tsai and Ghoshal 1998).

While shared cognition reduces relational uncertainty, opportunism increases it. Opportunism is self-interest seeking with guile, which involves distortion of information and reneging on explicit or implicit commitments (Jap and Anderson 2003). Between members from the two firms, when information is distorted through lying, cheating, or not fully disclosing, it becomes more difficult to predict others' behaviors due to a lack of accurate and timely information. Similarly, when promises and obligations cannot be fulfilled, anticipating the other party's actions becomes more difficult.

More shared cognition and less opportunism, or lower relational uncertainty, are more likely to be found among members from firms that have more collaborative relationships. Collaborative buyer-supplier relationships "are distinguished from arm's length exchanges by their (1) coordination efforts and (2) idiosyncratic investments" (Jap 1999, p. 464). Coordination efforts are manifested in the formation of "joint projects tailed to the dyad's needs", while idiosyncratic investments are non-fungible investments that uniquely support the relationship. Previous coordination efforts build the shared cognition, while idiosyncratic investments minimize opportunism.

Previous inter-firm coordination efforts build the shared cognition through engaging people from both firms in repeat collaborations . The team cognition literature has found that when team members interact with each other and gain expertise via a joint task, they gain knowledge that can help explain other members' actions, understand current task states, and develop accurate expectations about future member actions and task states (Cannon-Bowers and Salas, 1993). Similarly, the more a manufacturer works with a supplier on joint projects, the more likely people from the two firms are able to have shared representations, interpretations, and systems of meanings (Cicourel 1973). Such shared cognition enables members from one firm to know what to expect from people from the other firm, thus reducing relational uncertainty.

Inter-firm idiosyncratic investments minimize opportunism through aligning incentives. The non-fungible nature of idiosyncratic investments means that these investments lose their value if the relationship is terminated. Such investments facilitate expectations of continued exchange into the future (Heide and John 1990) and represent credible commitments to the relationship, both of which are useful in minimizing opportunistic behaviors (Williamson 1985). In surveying 136 collaborations between industrial buyers and suppliers, Heide and Miner (1992) confirmed that both extendedness of the relationship and frequency of contact will increase the chances that cooperative behaviors will occur.

Therefore, a more collaborative buyer-supplier relationship is associated with lower relational uncertainty in joint NPD projects. Through engaging in coordination efforts and investing in relationship-specific assets, both firms learn about and adapt to each other's specific goals, capabilities, environmental demands and human resources (Jap 1999, Dyer and Singh 1998). This learning and adaption process enables both firms to lower transaction costs and improve communication effectiveness (Dyer 1997, Asanuma 1989, Clark and Fujimoto 1991). The knowledge about and the experience of working with the other partner, built by either coordination efforts or idiosyncratic investments, reduces uncertainty when both firms work together in projects.

3.2.3 The communication-uncertainty fit

The propositions regarding the fit between communication intensity and technical/relational uncertainty are built upon Information Processing Theory, which has its roots in organizational design and coordination literature.

The organizational design literature has a tradition of theories that relate to the alignment of organizational structure and task environment (Lawrence and Lorsche, 1967; Thompson, 1967). Uncertainty, complexity and interdependencies are three major characteristics of a task. Galbraith (1973) defines uncertainty as "the difference between the amount of information required to perform the task and the amount of information already possessed by the organization". Complexity and interdependence in a business unit's task environment drive task uncertainty (Tushman and Nadler, 1978). High task uncertainty prevents organizations from being able to plan or make decisions about their task before it is executed (Milliken, 1987). Daft and Lengel (1986) found that formal organization structures determine both the amount and richness of information provided to managers. The appropriate organizational structure reduces task uncertainty and resolves task equivocality.

In addition to formal organizational structure, informal coordination mechanisms, such as unplanned face-to-face contacts between members from different teams, can also be used to manage task interdependencies. Malone and Crowston (1994) propose that coordination can be seen as a process of managing dependencies among activities. They claim that different coordination processes should be designed for different kinds of dependencies. Coordinating different types of interdependencies, such as functional, cognitive and structural interdependencies, affects the effectiveness of workgroups in different ways (Rispens, 2006).

Organizational coordination literature has proposed several types of coordination mechanisms to manage different levels of interdependencies. March and Simon (1958) argued that schedules and feedback mechanisms are required when interdependence is unavoidable. Thompson (1967) extended March and Simon's work by matching three mechanisms: standardization, plan, and mutual adjustment, to stylized categorizations of dependencies such as pooled, sequential, and reciprocal. Van de Ven et al. (1976) added a fourth approach, the team, which they distinguish from Thompson's mutual adjustment by the simultaneity of multilateral interactions and which typically requires physical proximity. Galbraith (1973) argued that low levels of interdependency can be managed by traditional mechanisms such as rules and programs. However, as the level of interdependency increases additional mechanisms are required such as slack resources and lateral communication (Galbraith, 1973).

Staudenmayer (1997) grouped the contributions of March and Simon, Thompson, and others into the information processing theories of interdependencies. From the perspective of Information Processing Theory (IPT), information processing is the underlying mechanism connecting either organizational structure with task environment. Information processing is the purposeful generation, aggregation, transformation and dissemination of information associated with accomplishing some organizational task (Robey and Sales, 1994). IPT explains that different coordination mechanisms, either formal organizational structure or informal coordination, have different information processing capacity. Furthermore tasks with different levels of interdependencies present different information processing requirements. The degree to which requirements and capacity are appropriately matched determines the quality of task outcomes (Galbraith, 1977; Tushman and Nadler, 1978). When information processing capacity is less than what is necessary to perform the task, performance standards will not be met, the task will not be completed on time, and/or the task will be completed at a higher than desired cost. On the other hand, when the organization employs an approach that provides more information processing capacity than is required, the task will be accomplished in an inefficient manner.

Although IPT is usually used to study coordination problems in an intraorganizational setting, it could be extended to an inter-organizational context. In a recent study adopting an IPT perspective, Stock and Tatikonda (2008) found that the match between task (external technology integration) uncertainty and interorganizational interaction leads to higher technology integration performance. Thus coordination mechanisms used in an inter-organizational context should also provide enough information processing capacity to manage the total uncertainty across organizational boundaries.

(1) The fit between communication intensity and technical uncertainty

In an intra-organizational context, empirical studies have found that outcomes are improved when coordination mechanisms that provide higher information processing capacity are used for more uncertain tasks. These studies verify that better organizational performance is the result of the fit between environmental dynamism and organizational structure organicity (e.g., Aiken, Bacharach, & French, 1980; Covin and Slevin, 1989)). The multi-contingency model built and tested in Gresov (1989) shows that a work unit that faces conflicted contexts, such as high task uncertainty with low external dependence, is less efficient than one that does not. The reason is that the presence of conflicting contingency increases the likelihood of misfit between structure organicity and task characteristics. Olsen et al. (1995) found that more participative coordination structures work better to improve product development performance when functional interdependency is high. In software development organizations, social-technical congruence, defined as the alignment between the structure of technical dependencies and developers' social coordination patterns, is found to be critical for improving software development productivity (Cataldo, 2007, Cataldo et al., 2008).

In an inter-organizational context, Heide (1994) found that task complexity and dependency drive more intensive coordination. Stock and Tatikonda (2008), adopting the IPT perspective, found that the match between task (external technology integration) uncertainty and inter-organizational interaction (effective communication, high degree of coordination and cooperative attitudes) leads to higher technology integration performance. Sobrero and Roberts (2002) examine performance implications of procedural coordination, varying on frequency, timing, media and directionality. Their findings, based on analysis of

50 manufacturing-supplier relationships in NPD, show that procedural coordination is a significant predictor for both type of relationship outcomes, either efficiency or learning. However performance implications of the fit between task characteristics and procedural coordination are neither theoretically proposed nor empirically tested in their study. Manil et al. (2007) is the only study that tested performance implications of procedural coordination and task characteristics (BPO process uncertainty). However, procedural coordination in their study is operationalized by levels of commitment, extent of joint effort and collaborative nature of performance metrics, which are less related with the level of information processing capacity and more with the level of inter-organizational collaboration.

In a technical uncertain product development project, intensive communication plays a greater role in improving both design quality and design efficiency. When the total project task is decomposed in a way that people from the firms are very interdependent with each other, intensive communication is necessary to make sure the design decisions made by each group does not cause any interference in the final design. When the technology being used is very novel, there is higher uncertainty regarding how to produce a high quality design in an efficient way. Therefore more intensive inter-firm communication enables more information, knowledge and skills to be integrated into the innovation process, which help shortens the learning process of getting familiar with the new technology and increases the probability of using the technology in the right way. When the product being developed is very complex, it is much more difficult to figure out the impacts of decisions made locally by one firm on activities conducted by the other firm. It has been shown that organizational boundaries can prevent teams working on interrelated components from interacting with each other in complex product development projects (Sosa et al. 2004). Therefore, intensive inter-firm communication is important for effectively managing design interfaces among interrelated components.

An example of negative effects of a lack of communication on product performance is the delay of the Airbus 380 project. "The root cause of the issue," said Christian, Airbus President and CEO, "is that there were incompatibilities in the development of the concurrent engineering tools to be used for the design of the electrical harnesses installation." A lack of communication among design teams causes the mismatch problem to be identified so late (when the electrical harnesses were installed into the fuselage) that a lot of rework has to be done, significantly delaying the project. In sum, in projects with higher technical uncertainty, intensive communication is more important in improving both design quality and design efficiency through preventing design interferences and reducing the amount of rework.

In a project with low technical uncertainty, inter-firm communication that is too intensive relative to uncertainty may waste engineering hours on non-value-adding coordinating activities. For instance, members from the supplying firm may be asked to formally document and periodically report their daily design activities to the buying firm, even when members of the buying firm does not need such communication to proceed with their own activities at all. In this case, the supplier's engineering time, which could have been devoted to designing a more innovative product, is wasted in non-value-adding bureaucratic communication. Therefore, the possibility of producing a high quality design is constrained in such a situation. Too much communication in projects with low technical uncertainty is also associated with less efficient development process. Time and costs are wasted on unnecessary communication, which "takes time and energy away from productive work", resulting in lower productivity (Hackman 1987). Lower productivity implies a lack of efficiency: the design group has to spend more time and incur higher cost in designing the component.

Therefore, I propose that:

Hypothesis 1a: The fit between communication intensity and technical uncertainty is positively associated with design quality.

Hypothesis 1b: The fit between communication intensity and technical uncertainty is positively associated with design efficiency.

(2) The fit between communication intensity and relational uncertainty

The team management literature has found that teams where members can anticipate future member actions are less dependent on explicit communication to coordinate interdependent activities. For example, the shared mental model literature found that members act in a highly coordinated fashion with very little communication in real-time teams performing in high-paced contexts, like sports competitions and medical emergency rooms, because of their prior experience working and/or training together (Cannon-Bowers et al. 1993, Klimoski et al. 1994, Kraiger and Wenzel 1997, Rouse and Morris 1986). The team cognition literature has found that teams that exhibit a "collective mind" or a "transactive memory", which help members to know where expertise is located in the team, are more coordinated (Faraj et al. 2000, Lewis 2000, Crowston et al. 1998, Weick et al. 1993). In such teams, members know whom they should ask for help for solving a certain type of problems, which reduces the need to use explicit communication in locating expertise.

From an IPT perspective, lower relational uncertainty suggests less information processing requirements in joint projects. When relational uncertainty is low, project members from each firm can develop accurate expectations about future actions of members from the other firm. Thus both firms can spend less effort in "explicit" coordination (Espinosa, 2002). Instead, interdependent activities conducted by both firms could be "implicitly" coordinated (i.e., without consciously trying to coordinate) through shared knowledge about the task and about each other. This shared knowledge helps members from both firms to anticipate what is going on with the task, what is going to happen next, who has the right resources, what procedures to follow, and which actions people from the other firm are likely to take, thus helping them become more coordinated. Therefore, explicit communication plays a smaller role in improving project performance.

Thus I propose that:

Hypothesis 2a: The fit between communication intensity and relational uncertainty is positively associated with design quality.

Hypothesis 2b: The fit between communication intensity and relational uncertainty is positively associated with design efficiency.

3.2.4 Main effects of goal congruence

Goals are concerned with desired future states of the world, and represent the underlying motives for intentional behavior (Mintzberg, 1983). Present actions can be characterized and attitudes toward future conduct can be defined by goals, explicitly or implicitly. Goals can be *explicitly* set by the dominant group or coalition within an organization (Cyert and March, 1992). For instance, cost, duration and quality are goals of a project explicitly set by project managers (e.g., Kerzner, 1997). Goals can also *implicitly* exist in actors' rational calculation process for maximizing self-interests (Bonner, 1995, Eisenhardt 1989). For instance, subordinates often, ignoring managerially prescribed goals, engage in opportunistic self-serving activities (Ouchi, 1979).

Goal congruence, in this study, is defined as the extent to which a buyer group and a supplier group perceive the possibility of common goal achievement (Jap 1999). Autonomous units often prioritize goals differently, due to their local expertise and social embeddedness in the institutional infrastructure of their respective "communities". A typical example is the conflict between engineers, marketing and procurement people in product design. Engineers usually want to create the most innovative design, while marketing focuses on satisfying customers' requirements and procurement wants to minimize costs. Such differences in goals will drive actors to adopt different solutions, which often conflict with each other due to the reciprocal constraining relationships among multiple goals. For example, in a satellite launch vehicle, lightweight structural material provides less radiation shielding. Thus to satisfy the radiation shielding goal, more shielding material around sensitive electronic components are needed, which, in turn, offsets some of the weight advantages of the lightweight material (Thomsen 1998).

Similarly, the buyer and supplier groups can differ in how they prioritize multiple project performance goals, such as cost, schedule, quality, etc., and product performance goals, such as weight, speed, size, etc., differently. Due to a lack of organizational slack, these goals often are reciprocal constraints to each other (March and Simon 1993). Achieving one goal tends to lead to a worse performance in others. Therefore, a lack of homogeneity in ranking multiple goals reduces the possibility of common goal achievement, or increasing goal conflicts (Thomsen 1998).

A lack of goal congruence is traditionally believed to be negatively associated with organizational performance. Conventional management and economic theories have demonstrated that deviation from managerially prescribed goals by subordinates will necessitate additional coordination and communication efforts to resolve the discrepancies (Eisenhardt, 1989; Levinthal and Fichman, 1988; Milgrom and Roberts, 1992). In team management literature, many studies suggest that a shared goal among team members improves with team effectiveness (e.g., Kristof-Brown and Stevens, 2001; Witt et al. 2001). The members who show congruity of peer goals feel better fit with team values (Vancouver and Schmitt, 1991), are more cooperative, and have more constructive interpersonal exchanges (Kristof-Brown and Stevens, 2001). Shared priorities enhance the single-minded direction that the project team is moving toward (Witt et al., 2001). In an inter-organizational context, goal congruence is shown to facilitate buyer-supplier collaboration (Jap 1999, Jap and Anderson 2003) and lower inter-organizational "friction cost" (Lakemond et al. 2006).

When a buyer group collaborates with a supplier group on developing a new product, both design quality and design efficiency are improved by inter-group goal congruence. When the two sub-groups share congruent goals, more efforts will be devoted to achieving the shared goals of the project; the two groups will have more high-quality communication; and both groups will be more willing to support and adapt to each other. All of these benefits result in higher component design quality. Furthermore, congruent goals held by the two sub-groups minimize inter-group friction, thus increasing design efficiency through improving productivity.

Thus I propose that:

Hypothesis 3a: Goal congruence is positively associated with design quality.

Hypothesis 3b: Goal congruence is positively associated with design efficiency.

(1) The moderating role of technical uncertainty-A group conflict management's perspective

Viewing conflicts from a process perspective, Thomas (1976) defined conflict as "the process which begins when one perceives that another has frustrated, or is about to frustrate, some concern of his" (Thomas 1976, p. 891). In a conflict episode, a basic sequence of events – frustration, conceptualization, behavior, outcome – occur as the system operates (Pondy 1967, Walton 1969). This process perspective provides a way of analyzing the mental and interpersonal events that lead to different conflict-handling modes and their consequences. Different conflict-handling modes, such as competition, compromise, avoiding, collaboration, and accommodation, vary on two dimensions: assertiveness and cooperativeness. Assertiveness measures the extent that one attempts to satisfy one's own concerns, while cooperativeness measures the extent that one attempts to satisfy others' concerns (Thomas and Kilman 1974, p. 11). The mix of conflict-handling modes in any relationship is shaped by cumulative effects of four classes of system variables: behavioral predispositions (e.g., preferred styles of the conflict parties), social pressures, incentive structures, and rules and procedures.

No matter how conflicts are resolved, an important assumption underlying the conflict management literature is that conflicts among group members have to be resolved before the group can move forward in accomplishing its tasks. Suppose design engineers want to use technology A for its superior functional capability, while manufacturing engineers believe that technology B is easier for production. In order to accomplish the product development task, the two groups need to agree on which technology to use. Thus, goal incongruence, a type of group conflicts, needs to be resolved.

High technical uncertainty suggests no one knows which solution and path is optimal. As defined in this study, a technical uncertain task environment suggests high inter-firm task interdependence, technological novelty, and/or product complexity. High inter-firm task interdependency suggests that the outcome of each firm's project tasks is highly dependent on activities of members from the other firm. This interdependence makes it difficult to evaluate the full impact of decisions made by one firm on the whole project. Projects using novel technology face higher uncertainty in terms of how to effectively use the technology to realize project goal. Similarly, the optimal solution and path are more challenging to obtain in projects developing complex products, such as airplane, automobiles, etc., due to the complex design and manufacturing dependencies among a large number of components.

When technical uncertainty is high, the negative effects of conflicts among group members are lower. As suggested by the conflict resolution literature, conflicts have to be resolved if the group wants to proceed with its tasks. In resolving the conflicts, to different extents, group members have to present their respective perspectives, knowledge and information and debate with each other in order to come to a common ground. Such a conflict resolution process forces team members to consider a wider of perspectives and paths, through which the decision quality is improved (Huber and Neale 1986, Thomsen 1998, De Dreu 2006). High technical uncertainty suggests no standard and routine solutions exist. Therefore it is more important for team members to scrutinize all possible solutions and to engage in deep and deliberate processing of task-relevant information. This process may generate highly creative insights (De Dreu and West, 2001; Jehn, 1995). In contrast, projects with low technical uncertainty often are full of highly routine tasks, which have effective standard processing procedures. It is quite easy to figure out the optimal path, which is often the routine path, leading to project success. Under such circumstances, diverse goals are more likely to interfere with this routine path rather than improving on it (Jehn 1995, De Dreu and Weingart, 2003).

Incongruent goals are most likely to be held by people with different functional and demographic backgrounds. The team management literature has shown a positive relationship between team diversity and team performance in highly uncertain task environment. When team members come from different demographic and functional background, they are very likely to form different opinions about what the tasks is and how the task should be accomplished. Such a diversity of unique cognitive attributes that members bring to the team increases team performance when task uncertainty is high (Cox & Blake, 1991; Hambrick, Cho, & Chen, 1996, Miller et al., 1998). A debate to resolve conflicts among different opinions and perspectives enhances creativity and innovation by generating greater variance in decision-making alternatives (Cox, 1993; Jackson et al., 1995). Team diversity in task-related and bio-demographic attributes has been shown to be especially important in improving decision quality when the task is complex, uncertain and interdependent (Horwitz and Horwitz 2007).

New data from experiments in social psychology indicate that an intermediate level of goal diversity may have potentially positive effects on group problem-solving performance (Amason, 1996; Jehn, 1995; Pelled, 1996; Watson et al., 1993). Goal diversity, on one hand, forces actors to consider a wider range of possible solutions to a problem, which increases the likelihood that a more ideal solution will be found. On the other hand, a lack of shared goals leads to a better understanding of the trade-offs associated with each solution, which improves solution quality for current problems and decision effectiveness for similar problems arising in the future (Kunda 1992).

Therefore I propose that:

Hypothesis 4a: The positive association between goal congruence and design quality is greater when technical uncertainty is high.

Hypothesis 4b: The positive association between goal congruence and design is greater when technical uncertainty is high.

(2) The moderating role of relational uncertainty-A group conflict management perspective

To realize the benefits of the goal conflict resolution process in increasing decision quality, it is important that team members have minimal relationship conflicts. Relationship conflict is an awareness of interpersonal compatibilities, includes affective components such as feeling tension and friction (Jehn and Mannix 2001). Relationship conflict involves personal issues such as dislike among group members and feelings such as annoyance, frustration, and irritation. It is detrimental to individual and group performance, member satisfaction, and the likelihood a group will work together in the future (Jehn, 1995; Shah and Jehn, 1993). When team members have low relationship conflict, they are more willing to participate into collaborative problem solving, an important mediating process linking the diversity in viewpoints pertaining to a group task and team innovation (De Dreu 2006).

Relationship conflicts are more likely to be found among team members who face low relational uncertainty. Relational uncertainty measures the extent to which members from one firm can confidently anticipate and explain actions of members from the other firm. Opportunism and a lack of shared cognition are two sources of relational uncertainty. The existence of opportunistic behaviors reduces trusts among members, which ultimately prevents open communication, lowers member satisfaction and commitment, and increases dysfunctional conflicts (Mayer et al. 1995, Gladstein 1984, Smith and Barclay 1997, Morgan and Hunt 1994). A lack of shared cognition, which helps team members to know where the expertise is and how to communicate with specific individuals, creates friction in task-focused interactions. For instance, a team member may get frustrated when participating in protracted discussions with another member who is not the expert for solving the focal problem. It is also possible that member A may feel personally offended when member B directly challenges his/her thought, without knowing that member B always talks in a straightforward way, no matter with whom. Team members who know more about each other are more likely to base their opinions on facts as opposed to stereotypes or superficial categorization, which contributes to lower relational conflicts (McShane and Von Glinow, 2000; Robbins, 2000; Rollinson, 2002).

Therefore, it is more important for members from the two firms to have congruent goals when their relational uncertainty is low. When relational uncertainty is low, members from the two firms are more likely to participate in collaborative problem solving. Only when team members are open to conflicting perspectives as well as willing to collaboratively resolve the conflict can the benefits of such diversity be realized (De Dreu 2006). On the contrary, when relational uncertainty is high, members from the two firms do not have much collaboration experience with each other and are likely to behave opportunistically to fulfill self-interests. Under such circumstances, it is more challenging for members from the two firms to resolve conflicts in goals due to a lack of common understanding and the abundance of opportunistic behaviors. Therefore, the benefits of goal conflict in terms of improving decision quality, on one hand, are less likely to be realized. On the other hand, conflicts in goals, if not well resolved, may even cause relational conflicts, which are detrimental to project outcomes.

Thus I propose that:

Hypothesis 5a: The positive association between goal congruence and design quality is greater when relational uncertainty is high.

Relational uncertainty also strengthens the positive effect of goal congruence on design efficiency. On one hand, a low relational uncertainty environment can facilitate resolving conflicts in goals in a more timely fashion with lower costs incurred. Therefore, team members can realize an efficient process even when they have conflicting goals. One the other hand, it is more important for team members to share compatible goals when they do not know each other well in order to be efficient. The reason is that they do not have the luxury of being capable of resolving conflicts in an efficient and effective way.

Hypothesis 5b: The positive association between goal congruence and design efficiency is greater when relational uncertainty is high.

Figure 3-1 shows the conceptual model with two moderators: technical uncertainty and relational uncertainty.

FIGURE 3-1 The Moderating Model

3.3 The mediating model: Collaboration Quality

3.3.1 Collaboration process and collaboration quality

Following the literature, collaboration can be defined as a process of joint decision making involving people with diverse interests to achieve a common purpose via interactions, information sharing and coordination of activities (Jassawalla and Sashittal 1998, p. 239, Amabile et al. 2001, Gray 1989, p. 11). There are four basic elements of this definition: (1) process, (2) diverse interests, (3) a common purpose, and (4) interactions. In the problem context of this study, the buyer-supplier collaboration is a process where the buyer group and supplier group, with diverse interests, interact with each other for the common purpose of delivering a product design in an efficient and effective way.

Collaboration quality measures the extent to which a collaboration process is effective. According to the definition above, a high-quality collaboration process should have effective inter-unit interactions, which mediate the effects of inputs (diverse units) onto outputs (the common purpose) (Steiner 1972, McGrath 1984, Hackman 1987). The literature suggests that effective interaction among work group members are indicated by sufficiency of efforts, the right mix of knowledge and skills applied to the task, and choosing the right task strategy (Hackman 1987). Similarly, high-quality interactions within a team are indicated by high-quality communication, mutual support, coordination (as an outcome), balance of member contributions, effort, and cohesion (Hoegl and Gemuenden 2001). What to be noted is that coordination here does not refer to the coordinating process, defined as activities carried out when managing dependencies. It is an outcome, indicating the extent to which dependencies are effectively managed (Espinosa et al. 2002).

Building upon the work group and team management literature, five facets of a collaboration process are proposed to capture the nature of interactions in a collaboration process. They are: sufficiency of efforts, mutual support, coordination, communication quality and knowledge/skill-based contributions (Hackman 1987, Hoegl and Gemuenden 2001). A high-quality collaboration process has high values on all the five facets: (1) enough efforts are applied to tasks, (2) partners mutually support and adapt to each other in carrying out tasks, (3) individual efforts are well structured and synchronized, (4) accurate and relevant information is exchanged in a timely fashion, and (5) every partner is able to contribute all task-relevant knowledge and experience to tasks.

Cohesion, a measure of the degree to which team members desire to remain on the team/group, is not included. According to Hackman (1987)'s work group effectiveness theory, the effectiveness of a group process is measured by whether enough efforts and knowledge are applied to the task and whether the right task strategy is chosen, both of which focuses on the group task. Cohesion, unlike the other five facets, does not directly measure the extent to which the group process helps task completion. Therefore it is not included as a facet of collaboration quality.

3.3.2 Collaboration quality and design performance

Hackman (1987) proposed a normative model of group effectiveness (Figure 3-1) which aims to "identify factors that most powerfully enhance or depress the task effectiveness of a group and to do so in a way that increases the possibility that constructive change can occur". In the group effectiveness model, the design of a group: task structure, group composition, and group norms, and organizational context: the reward, education and information systems, directly affect group process effectiveness. Both group design and organizational context act as initial conditions *designed* to affect group process effectiveness. Process effectiveness, a state emerging from group interactions, is measured by the (1) level of effort brought to bear on the group task, (2) amount of knowledge and skill applied to task work, (3) appropriateness of the task performance strategies used by the group. Group effectiveness is indicated by (1) performances of group output, (2) group member satisfaction, and (3) group members' capability to work together in the future. Hackman also mentions two moderators, group synergy and contextual supports, which "tune" main effects in the model.

Hackman's model has been used to descriptively analyze various kinds of teams in different types of organizational settings (see Hackman 1990). Empirical evidence has been found supporting different parts of the model. For instance, effects of group design factors, such as group autonomy (Seers, Petty and Cashman, 1995, etc.), task characteristics (Wageman 1995, etc.), group diversity (Campion et al. 1993, etc.)and size (Steiner, 1972, Vinokur-Kaplan 1995, etc.), on process effectiveness have been widely studied. Organizational context, such as rewards (Campion et al. 1993, etc.) and supervision (Cohen et al. 1996, etc.), are also found to affect process effectiveness in work groups. Among few studies which test Hackman's model in a comprehensive way, Vinokur-Kaplan (1995) found that particular initial and enabling conditions, such as group size, task clarity, environmental supports, group interdependence, etc., significantly affect group process effectiveness, indicated by standards met, team cohesion and individual well being, which ultimately affect team effectiveness.

INSERT FIGURE 3-2 HERE.

From the perspective of work group effectiveness theory, collaboration quality, an indicator of process effectiveness, should improve performance of a BG-SG dyad in terms of delivering a better design. A BG-SG dyad with high inter-group collaboration quality is characterized by high-quality communication, mutual supports, high commitment to the projects, well-coordinated individual efforts and knowledge/skill-based contributions (Hoegl and Gemunden 2001, Hoegl and Wagner 2005). These characteristics are all associated with higher design quality and design efficiency. Thus I propose that:

Hypothesis 6a: Collaboration quality is positively associated with design quality.

Hypothesis 6b: Collaboration quality is positively associated with design efficiency.

3.3.3 Collaboration quality as a mediator

According to Hackman's model, collaboration quality serves as a mediator transferring effects of organizational context on group performance. Organizational context factors include the reward, education, and information systems that influence the group, and the material resources that are put at the group's disposal. Extending this model to an inter-organizational context, I propose that effects of coordination fit and goal congruence are partially mediated through collaboration quality.

Inter-firm communication functions as an information system in improving process effectiveness. An organizational information system provides information for a group to "plan and execute a task-appropriate performance strategy" (Hackman 1987, pp. 330). According to Hackman, an information system in the organization where the group works could (1) increase clarity about parameters of the performance situation, and (2) provide access to data about likely consequences of alternative strategies. These two outcomes could increase the likelihood that the group selects the right strategy to perform the task (Hackman 1987). Similarly, when a buyer group and a supplier group exchange information to coordinate interdependent activities, the collaboration process becomes more effective.

Inter-firm communication has the potential in improving all the five dimensions of collaboration quality. The more the two groups communicate, the more likely that high-quality information is exchanged in a timely fashion. Frequent inter-firm communication helps promote a cooperative atmosphere where mutual adaption and open idea exchange could happen. Because the main reason for inter-firm communication in the joint project is to solve task-related problems, intensive communication forces both firms to devote more efforts to the joint project. Without exchanging updated information about the status of interdependent tasks, there is no way to ensure that the different tasks conducted by members will align. The more the two sub-groups communicate, the more likely they are able to identify each other's strengths and weakness, which facilitate more balanced and knowledge/skill-based contributions from both sides.

Thus I propose that:

Hypothesis 7: Communication intensity is positively associated with collaboration quality.

Goal congruence plays the role of a reward system in improving process effectiveness through aligning incentives of group members. According to Hackman, "A supportive organizational reward system can reinforce the motivational benefits of a well-designed team task". Reward systems that support high effort by work teams tend to have (1) challenging and specific performance objectives, (2) positive consequences for excellent performance, and (3) rewards and objectives that focus on group, not individual behavior. In short, an effective reward system could align incentives of all the group members to work hard on group task, thus increasing sufficiency of efforts applied to the group task, another criterion of process effectiveness.

Similarly, when a buyer group and a supplier group have congruent goals, collaboration process effectiveness is improved. When the two groups have congruent goals, their efforts are channeled towards the same target, thus increasing the amount of efforts applied on productive design activities. If the two groups have congruent goals, they are more likely to mutually support each other to adapt to changes. Congruent goals held by the two groups also motivate them to share high quality information in a timely fashion.

Congruent goals will also motivate people to contribute all the relevant knowledge and skills to project tasks and consider the interdependency among individual efforts to reduce interferences. Thus I propose that:

Hypothesis 8: Goal congruence is positively associated with collaboration quality.

Without improving the effectiveness of the collaboration process, there is no way that communication intensity and goal congruence could improve project performance. According to Hackman (1987), group process effectiveness fully mediates the impacts of organizational context and group design factors on performance of work groups. Similarly, without increasing collaboration quality, intensive communication and congruent goals improve neither design quality nor design efficiency. For instance, the inter-firm communication could be full of inaccurate or dated information. Thus even if the communication is frequent and intensive, neither design quality nor design efficiency can be improved. Similarly, people from the two firms may share exactly the same goals. However, if the congruent goal structure do not transform into coordinated activities and sufficient efforts, neither design quality nor design efficiency can be improved.

Thus I propose that:

Hypothesis 9a: Collaboration quality fully mediates the effects of communication intensity and goal congruence on design quality.

Hypothesis 9b: Collaboration quality fully mediates the effects of communication intensity and goal congruence on design efficiency.

Figure 3-3 shows the mediating model

INSERT FIGURE 3-3 HERE.

Table 3-1 Nominal definitions and operational dimensions of constructs

Construct	Nominal Description	Operational Dimensions
Technical Uncertainty (TU)	The total task uncertainty faced by project members from the two firms in developing the product (Galbraith 1973)	1. Task interdependence 2. Technological Novelty 3. Product Complexity
Relational Uncertainty (RU)	The difference between the information members from one firm need and the information that they have in anticipating actions of members from the other firm (Galbraith 1973, Jap 1999)	1. Previous collaboration 2. Idiosyncratic investment
Communication Intensity (CI)	The frequency and intensity of communication between members from the two firms.	1. Frequency 2. Intensity
Goal Congruence (GC)	The extent to which a buyer group and a supplier group perceive the possibility of common goal achievement (Jap 1999).	Single dimension.
Collaboration Quality (CQ)	The extent to which a collaboration process is effective (Hackman 1989)	1. Mutual supports 2. Communication quality 3. Sufficiency of efforts 4. Coordination 5. Knowledge/skill-based contributions
Design Quality (PD)	The degree to which the design met performance goals related to its fitness for use (Swink and Calantone 2004).	1. Dimensional integrity 2. Durability 3. Functionality 4. Manufacturability 5. Fit customers' needs
Design efficiency (PE)	The extent to which resources are fully utilized on productive design activities (Hoegl and Gemuenden 2001)	1. Developmentt cost 2. Development time

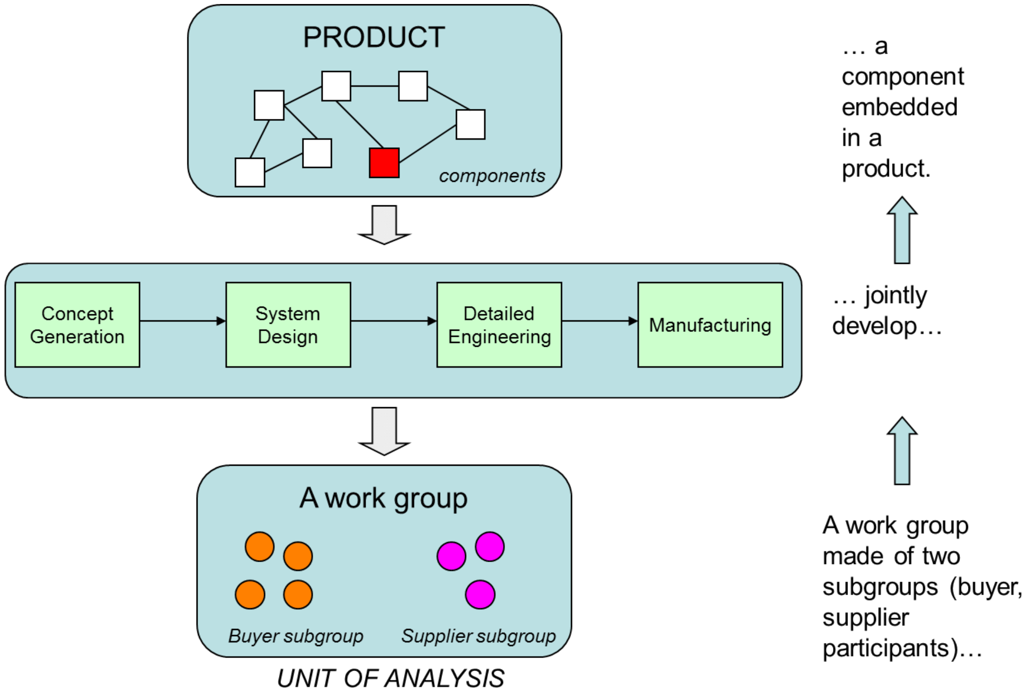


Figure 3-1 Research context and scope

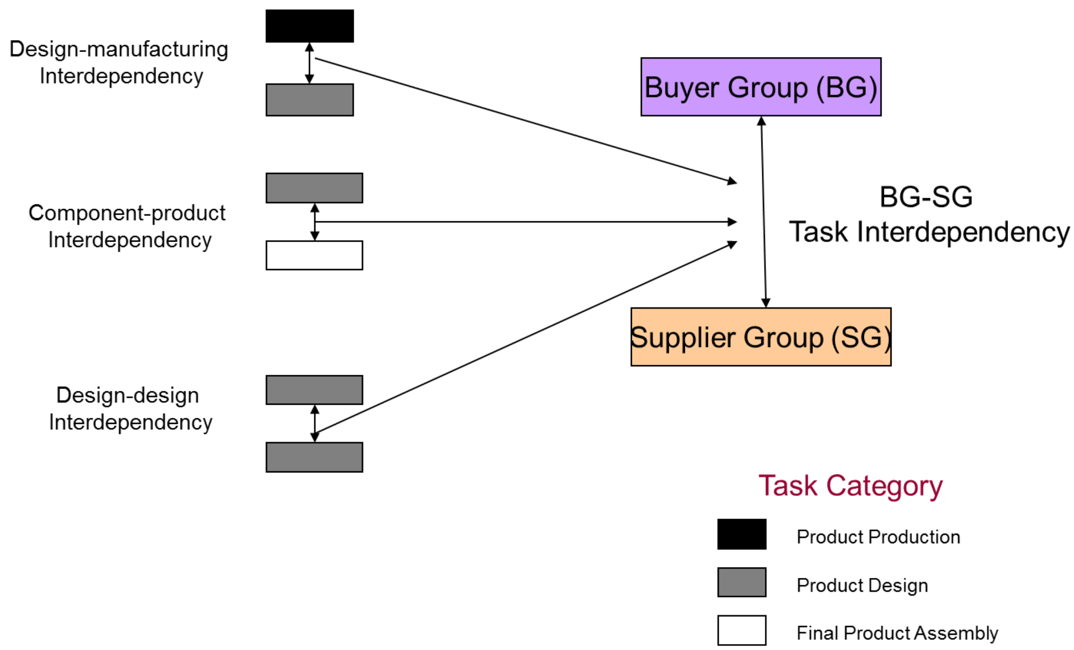


Figure 3-2 Three sources of buyer-supplier task interdependency

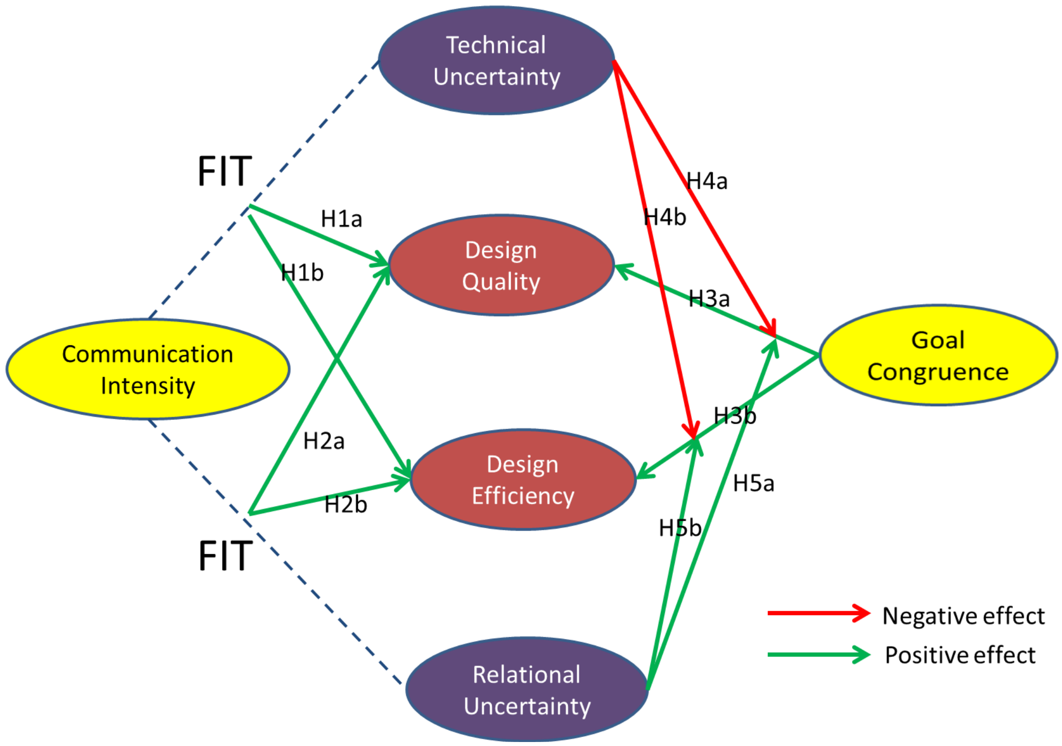


Figure 3-3 The Moderating Model

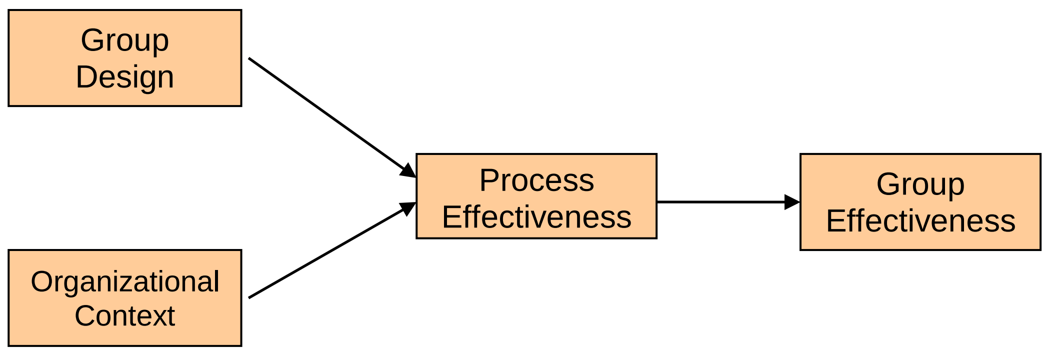


Figure 3-4 Hackman's theory of group effectiveness (adapted from Hackman 1987)

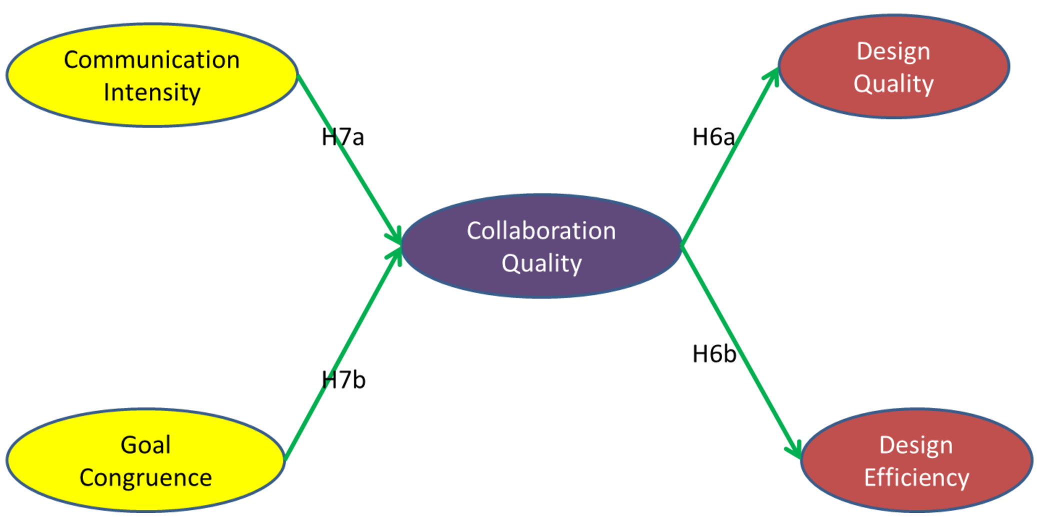


Figure 3-5 The Mediating Model

4 METHODOLOGY

4.1 Research methodology

There are three possible research approaches for testing my hypotheses: controlled experiments, case studies and surveys. While any of the three forms would have been suitable, I considered the use of empirical surveying for particular reasons. Considerations for selecting these three candidate methodologies and reasons for my final choice are explained below.

The experiment is a situation in which a researcher objectively observes phenomena that are made to occur in a strictly controlled situation where one or more variables are varied and the others are kept constant (Cook et al. 1979). It is a classical method for identifying cause-effect relationships through adequately controlling confounding variables (Bendoly and Cotteleer 2008). There are many studies using controlled experiments in the field of new software development, a special type of new product development (see Sjoberg et al. 2005 for a review). However, one limitation of this approach is difficulty in manipulating the problem context, which endangers external validity. My interest in studying product-process fit and design-manufacturing coordination in a buyer-supplier collaboration context increases the difficulty of appropriate manipulation. First, design-manufacturability is not a meaningful performance measure for most products that are suitable for conducting lab-based controlled experiments, such as software. For these products, detailed designs are the final products (there are no separate manufacturing processes for such products). Second, even if I could identify an appropriate product, the design-manufacturing coordination is difficult to manipulate in a lab setting. For example, it is difficult to simply assign a subject to the manufacturing function, provide him/her with some basic manufacturing process information, and then assume the subject acts the same way as a real-life manufacturing engineer. Finally, it is difficult to manipulate the buyer-supplier collaboration context. For example, I can not just assigning subjects to either the buyer or the supplier group and then assume there exists an organizational boundary between subjects in the two groups.

The case study is a research strategy that focuses on understanding the dynamics present within single settings. It is especially suitable for explorative studies focusing on building theories (Eisenhardt 1989). The focus of this study, which is to test applicability of existing theories in a new problem context, limits the potential of using case study to generate generalizable insights. The need for a large number of unique cases, in this study buyer-supplier dyads, to capture enough variation in communication and goal structures, uncertainty and collaboration quality makes case studies a less efficient research method.

There are several benefits associated with using surveys for this study. First, a survey, compared with using archival data, is superior in generating original data that better measures theoretical constructs. In this study, collaboration quality, for example, could be *directly* measured through asking respondents a set of questions regarding their collaboration process with partners, instead of being *indirectly* measured by manipulating data that is not created for the purpose of this study. Second, a survey is an appropriate method for capturing actual behavior (Flynn et al. 1990). Surveying, compared with other deductive research methods, relied less on constraining assumptions when studying complex problems. In this study, the complex effects of over- and under-coordination on different types of design performances are studied in their real-life contexts, instead of being simplified into quantitative cost-benefit analysis. Lastly, using a survey is efficient in generating a sample large enough for statistical generalization. As Babbie (2004) notes, survey research is the best method available for "collecting original data for describing a population too large to observe directly" (2004, pg 243).

4.2 Survey instruments and construct operationalization

A survey instrument is developed to capture the main and contingency relationships of the conceptual model noted earlier. I use existing scales whenever possible, modified for the purpose of this study. Built upon existing literature, four new scales, product complexity, task interdependence and collaboration quality, are created. Table 4-1 shows all the items used to measure the constructs. The primary unit of analysis is each BG-SG dyad.

To help enhance the validity of the findings, I applied a two staged data collection approach, which involved pre-testing and then testing (Malhotra and Grover, 1998). Pre-testing of the survey is done through asking both academic researchers and practitioners from various target industry groups to evaluate each item in terms of concept and instruction clarity, lack of ambiguity, flow and ease of use. The pre-testing procedures led to some rewording and reordering of questions. In the next section, I explain the process of selecting and refining each of the constructs.

4.2.1 Main constructs

(1) Communication intensity

The scale is adopted from Hoegl and Wagner (2005). The two items ask the intensity and frequency of communication between project members from the two firms.

(2) Task interdependency

The scale measuring task interdependency is adopted from Gresov (1989). The data used in Gresov (1989) were measured with the Organization Assessment Instrument (OAI) developed and evaluated by Van de Ven and Ferry (1980). The inter-organizational dependency scale, composed by three items, is slightly modified to fit a BG-SG dyad context in NPD projects. For instance, "people in other organizations outside Job Service Division" is changed into "people from one firm have to depend on people from the other firm".

(3) Product complexity

Adopting a complexity science perspective, this study creates a new scale, composed by four items, to measure product complexity. Building on definitions of complexity used by Kauffman (1993), Waldrop (1992), and Dooley (2001), we define product complexity as a factor of the number of components, the degree to which these components vary and the level of design interdependence (e.g., shared design interfaces). In short, complexity "appears to refer to the load on the system that requires coordination—the higher the differentiation and the loose coupling among the elements in the system, the higher the load required to coordinate the system" (Choi and Hong 2002). Unlike most other product complexity scales used in the literature that only measure the number of components or functions (Swink 1999, Griffen 1997), this scale captures all three dimensions of a complex system product. Respondents are asked to assess each dimension for the focal product relative to similar or substitute products.

(4) & (5) Product and Process Technology novelty

Two scales adopted from Tatikonda and Rosenthal (2000): product and process technology novelty, are used to measure technology novelty, as two separate latent constructs. Both scales measures the newness of the technologies employed in the product development effort. The operationalization of product technology novelty includes new product architectures in addition to new product parts and modules, and the operationalization of process technology novelty includes new manufacturing flows and layouts in addition to specific new manufacturing tools and process stages.

(6) Goal congruence

Goal congruence between the two sub-groups is measured using the scale developed by Jap (1999) composed by four items. One item, "Members from the buyer and supplier firms have *different* goals", is rewritten as "Members from the buyer and supplier firms have goals that are *in conflict with* each other". Another item, "members from the buyer and supplier firms share the same goals" is replaced by an item asking the extent to which members from one firm felt it is highly likely to realize both their goals and the other firm's goals. The reason is that congruent goals are not necessarily shared goals. Furthermore, inter-firm congruence in both project performance goals, such as cost, schedule, etc., and product performance goals, such as weight, size, speed, etc. are measured. Respondents are asked to assess the congruence at the time when the buyer firm started to involve the supplier in the project.

(7) Coordination efforts

This scale is adopted from Jap (1999)'s three item scale. Each item is slightly rephrased to fit the context of this study. For instance, "they work on joint projects tailored to their needs" is rephrased as "Our firm works with this supplier on joint projects tailed to our respective needs".

(8) Idiosyncratic investments

This scale is also adopted from Jap (1999)'s three item scale. Each item is slightly rephrased to fit the context of this study. For instance, "if this relationship were to end, they would be losing a lot of knowledge that's tailored to our relationship." is rephrased as "If our relationship with the supplier were to end, both firms would waste a lot of knowledge that's tailored to our relationship".

(9) Collaboration quality

Hoegl and Wagner (2002) developed a scale for measuring buyer-supplier collaboration quality, built upon the operationalizations and discussion of related constructs by Hoegl and Gemuenden (2001), Littler et al. (1998), Ragatz et al. (2002), and Tjosvold (1984). Mutual supports, sufficiency of efforts and communication quality are derived from Hoegl and Wagner (2002)'s scale. Coordination is measured by a scale developed by Sivadas & Dwyer (2000). Knowledge/skill-based contributions are measured by the scale measuring balance of member contribution, developed by Hoegl and Gemuenden (2001).

(10) Design quality

The scale measuring design quality is built upon Hoegl and Wagner (2005), Hoegl and Gemuenden 2001, Swink and Calantone (2004) and Takeishi (2001). Each of the six items is the product of goal aggressiveness and the extent to which each goal is achieved. Thus, given a particular level of goal achievement, design quality is higher if the goal is more aggressive. The six-item scale measures the extent to which a component design is dimensionally integral (no interferences with other components), durable, functional, manufacturable and fits target customers' needs, after controlling for the aggressiveness of each dimension.

(11) Design efficiency

Design efficiency is measured by a four-item scale adapted from Swink's (1999) manufacturability scale. Development cost and time goal achievements are each measured by two items respectively. One item is a product of goal aggressiveness and the extent to which the budget/time goal is achieved. The other one asks to what extent the development cost/time was low/short.

4.2.2 Control variables

(1) Company demographic background

Companies in different countries (e.g., United States and China) with different sizes, sales and ages may differ in their project management capabilities, collaboration competences and innovation potentials, all of which may affect performances of NPD projects. So I control for potential effects of the manufacturers' locating country, number of employees (log), sales (log) and ages (log) on both types of project performances. The number of employees and sales are formed as two items measuring firm size, a latent construct.

Industry, as a categorical variable with 16 categories, is not entered into the model as a control variable for two reasons. First, preliminary analysis does not show that industry has a significant impact on either design quality or design efficiency. No significant correlation is found between any one of the 15 industry dummy variables and any of the two performance measures (design quality and design efficiency), both calculated as summed averages of all the items composing them. Similarly, one-way ANOVA analysis shows that both design quality (PD) and design efficiency (PS) do not differ significantly across industry groups (Table 4-1). Second, adding 15 binary observed independent variables to either a moderated or mediated SEM model creates convergence problem due to loss of degree of freedom as well as the existence of too many single-indicator latent constructs (each dummy variable is treated as a single indicator latent construct with no measurement error in LISREL).

INSERT TABLE 4-1 HERE.

(2) Supplier involvement timing

Early involvement of suppliers in development is believed to reduce development time, eliminate production problems for both suppliers and their customers, and increase product quality (Clark 1989, Blenkhorn and Noori 1990, Hartley et al. 1997). It has been found that project team effectiveness have a greater affect on design performance when suppliers who were integrated earlier in the new product development process (Petersen et al. 2005). Wasti and Liker (1997) found evidence of improved performance when suppliers were involved earlier in product development efforts. There is evidence to show that earlier integration is beneficial in cases of higher technology uncertainty (Petersen et al., 2003); however, the benefits of doing so are also countered by the disadvantages of being "locked into" a particular supplier, especially when there are multiple competing technologies vying to become the industry standard (Handfield et al., 1999). Thus we can see that supplier involvement timing is a significantly associated with product development performance in different ways. Building on existing literatures (Hartley et al. 1997, Petersen et al. 2005, etc.), timing of a supplier's involvement is measured by asking at which stage the supplier started being involved in the project.

(3) Task relevant expertise

Sufficiency of knowledge and skills applied to the group task is an important criterion of group process effectiveness, which contributes to better group performance (Hackman 1987). One important group design factor, individual members' task relevant expertise, is significantly associated with the amount of knowledge and skill members apply to their tasks. It is important to accurately recognize and effectively utilize such expertise in work groups to improve group performance (Bunderson 2003). In the context of this study, a group of design engineers and other professionals, either from the buyer or the supplier firms, collaborate on the detailed design of a physical product. Their task relevant expertise (TRE), independent with either coordination structure or collaboration quality, should be positively associated with design performance.

The scale measuring task relevant expertise is built upon Netemeyer and Bearden (1992)'s five-item, 7-point semantic differential used to measure word-of-mouth source expertise perceived by consumers. Five items are respectively built upon the five semantic differential items: knowledgeable-not knowledgeable, competent-incompetent, trained-not trained, expert-nonexpert, and experienced-not experienced. An example item is "We are knowledgeable about designing the product". Respondents are asked to indicate the extent to which they agree with the statement (5= agree, 1= disagree). The five items are summed to form an overall index.

INSERT TABLE 4-2 HERE.

4.3 Data selection and sampling technique

Survey responses were gathered from different NPD projects in firms crossing multiple industries and two countries to increase generalizability of results from this study. Manufacturing firms that integrate and assemble complex and discrete products, such as airplanes, automobiles, ships, computers, mobile phones, medical equipment, for end consumers were my targets. Survey responses were collected in two countries, United States and China.

To ensure content invariance between the English and Chinese surveys, the English version of the survey was translated by one translator into Chinese, then translated back into English by another bilingual translator. A third person checked for inconsistency between the original English survey and the translated English survey to correct for any problem in the translation.

Contact information for the respondents was purchased from Lead 411, a public lead company, for the United States sample and was extracted from member listings of manufacturer associations for the Chinese sample. Target respondents at each firm were product development managers, engineering managers, senior buyers and supply chain managers involved in new product development projects. I considered these professionals to be best suited for the study as they are often key project members involved in collaborative product development projects involving suppliers.

To control for bias related with a single respondent, two different project members from each manufacturer responded to two different parts of the survey. The project manager was asked to provide information on project performance and all the control variables. The project manager also provided the contact information of one key project member, who actively participated in the project and interacted with the supplier during the project. The second respondent was asked to provide information on how project members from the two firms interact with each other during the project.

To control for bias related with single data collection method, two methods were used in collecting the data: on-line and hard-copy. A two-part on-line survey was hosted on Survey Monkey (www.surveymonkey.com). The first parts of the survey were sent to 2000 contacts in the United States on June 14th, 2010. One week after the first round on June 22nd, another round of emails were sent to non-respondents in the first round. The third round surveys were sent out to non-respondents in the first two rounds two weeks after the second round on July 7th 2010. Part II of the survey, thus, was sent in emails to those identified, followed by two rounds of phone calls. To make sure the second respondent refers to the same project and same supplier to which the first respondent refers, each Part II of the survey contains specific information about the project, such as project name, product name, project staring year and supplier name, provided by the first respondent. Mailed surveys were sent out (followed by two rounds of phone calls) to identified firms in both United States and China. In total, 426 completed surveys, out of 2625 contacted, were collected, with 214 from the United States and 212 from China, generating a response rate of 16.23%. Table 4-3 shows the response rate distribution with each method and in each country.

INSERT TABLE 4-3 HERE

4.4 Data Validation

I prescreened the data using the PRELIS procedure (Joreskog, 1999) prior to being fit into confirmatory factory analysis models. Survey results collected using Likert scales are essentially ordinal in nature, whereas modeling software requires interval scales with normal distribution. Such misuse of data can lead to large negative biases (Carroll, 1961). Also, combining un-scaled multiple indicators to capture a single latent variable without consideration of the importance of each indicator can also lead to misleading estimates. Bollen (1989) denotes excessive kurtosis and skewness, stronger influence on chi-square estimate and attenuated standardized coefficient estimates as possible consequences of treating ordinal measures as continuous.

Confirmatory Factor Analysis (CFA) was utilized to validate the scales used in this study as they were developed based on theories found in the current literature (Ahire and Devaraj, 2001; Hatcher, 1994; Malhotra and Grover, 1998). The scale validation process assessed measurement invariance, unidimensionality/convergent validity, reliability, and discriminant validity of the measurement models representing the constructs in this study. A holistic measurement model was utilized for the CFA—this approach is preferable over independent CFA testing of each construct individually (Kroes and Ghosh 2010).

4.4.1 Measurement invariance

Before combining samples to test reliability and validity of latent constructs, I use two-group structural equation modeling (SEM) to assess measurement invariance across the two countries as well as across samples collected using the two methods. Specifically, I want to test whether the same factor model holds for different populations under study (Arbuckle and Wothke, 1999; Byrne, 2001; Little, 1997). There are different levels of measurement invariance: configural invariance, metric invariance, scalar invariance, factor variance invariance, and error variance invariance (Vandenberg and Lance 2000). A test of configural invariance is a test of a "weak factorial invariance" null hypothesis (Horn and McArdle 1992) in which the same pattern of fixed and free factor loadings is specified for each group. Configural invariance must be established in order for subsequent tests to be meaningful. A test of metric invariance, or a test of strong factorial invariance, is that loadings for like items are invariance across populations. At least partial metric invariance needs to be established before tests of factor variance and error variance invariances to be meaningful. A test of factor/error variance invariance is a test that factor/error variances are invariant across populations.

The types of measurement invariance that need to be established vary by the goal of the study (Steenkamp and Baumgartner 1998). The literature has shown that a lack of error invariance does not create a problem as long as differences in measurement errors are explicitly taken into account (which is the case in latent variable modeling) (Vandenberg and Lance 2000). Only when researchers want to compare standardized measurements of association (correlation coefficients, standardized regression coefficients) across populations is factor variance invariance required (Pedhazur 1982, Steenkamp and Baumgartner 1998). Neither of these criteria apply to this study. Therefore, only configural and metric invariance need to be established before we can combine the two samples and test hypotheses.
Table 4-4a and 4-4b show results from the two-group SEM analysis. Each row shows fit indices of one confirmative factor analysis model. The configural invariance model only constrains the same factor structure (patterns of zero and free factor loadings) to be invariant across the two samples. The metric invariance model further constrains factor loadings to be the same across the two samples. The full invariance model further constrains every other estimated parameter (e.g., error variances, intercepts, covariance and means of factors) to be invariant. The full invariance model is nested in the metric invariance model, which is further nested in the configural invariance model. Fit indices for all the three models in both tables show moderately good fits according to fit criteria suggested by the literature: RMSEA<0.06, NFI>0.90, NNFI>0.90 and CFI>0.90 (Steenkamp and Baumgartner 1998, Vandenberg and Lance 2000). Furthermore the two insignificant chi-square difference tests in each table shows the full invariance model fits the data no worse than the metric invariance model does, which further fits no worse than the configural model. Thus full measurement invariance can be established between both the U.S. and

China, and the Online and Mail samples. This conclusion allows us to the combined sample in all the following data validation tests.

INSERT TABLE 4-4 HERE

4.4.2 Unidimensionality and Convergent validity

Unidimensionality is the existence of a single construct underlying a set of measures or empirical indicators (Gerbing and Anderson, 1987; O'Leary-Kelly & Vokurka, 1998). Convergent validity measures the degree to which different methods for measuring the same variable produce similar results. Unless multiple methods for data collection have been used, tests for unidimensionality and convergent validity are the same. There seems to be general agreement in the OM literature on the viability of using CFA as a "rigorous and precise" (Garver and Mentzer, 1999; pg 40).

To test for unidimensionality/convergent validity, a CFA model with all the 12 latent constructs is evaluated (Garver and Mentzer, 1999). LISREL 8.72 is used to develop the model on the full set of data (n=426) (Bollen, 1989; Kelloway, 1998; Shah and Goldstein, 2006). Items for each construct are only allowed to load on the corresponding construct. Variances of all the 12 latent constructs are constrained to be 1 in order for the model to be identifiable. Error covariance between items is constrained to be zero. The only two pairs of freely estimated error covariance are between PS1 and PS2, and between PS3 and PS4, the four items measuring design efficiency. The reason is that the two items in each of these two pairs share one common item in their composition. For example, PS1 is the product of the first item in the design efficiency scale (PE1: Our budget goal for the project was fully achieved) and the first item in the design efficiency goal aggressiveness scale (PSA1: The development budget goal for this product was very aggressive). PS2 is the product of the second item in the design efficiency scale (PE2: The development cost for this product was kept low) and PSA1. Thus PS1 and PS2 share PSA1 in their compositions, which means both PS1 and PS2 are exposed to the same unique variance associated with PSA1. Thus we could expect correlated residuals between PS1 and PS2. The same is true for PS3 and PS4.

To evaluate convergent validity/unidimensionality, model fit indices and parameter estimates in the holistic CFA model involving all the 12 constructs are used. Model fit indices evaluate the arrangement of scales while parameter estimates (latent variable paths) are indicators of how closely the scales are related to the underlying construct. Multiple model fit indices could be used to evaluate the overall model fit. The Chi Squared Goodness of Fit statistic indicates the magnitude of discrepancy between the sample and fitted covariance matrices. However, Chi Squared statistic can be sensitive to sample size (especially when sample size goes beyond 200) and can be misleading (Garver and Mentzer 1999). Thus following existing norms (Hu and Bentler, 1999; Shah and Goldstein, 2006, Garver and Mentzer 1999), I also report absolute fit indices, RMSEA, GFI and SRMR and incremental fit indices, CFI and NFI. Parameter estimates should be significant at the 0.05 level with loadings near or above 0.70. Anderson and Gerbing (1991) suggest that evidence of convergent validity exists if the manifest variable loads significantly (t-value > 2.58, p <0.01) on its respective latent variable, in addition to a good fit of the overall CFA model to the data.

Results for the CFA model showed Chi square (df) of 2833.06 (1364), RMSEA = 0.048 with a 90 percent confidence interval of (0.045, 0.051), the p-value for RMSEA to be less than 0.05 is 0.88; SRMR=0.048; NNFI=0.96; CFI=0.96; IFI=0.96. RMSEA and SRMR values falling below 0.08 are acceptable, while NNFI, CFI and IFI should be at least 0.90 and approaching 0.95 (Bollen 1989; Hatcher 1994; Bentler and Bonett, 1980; Garver and Mentzer 1999; Hu and Bentler, 1999). According to these benchmark values, the holistic CFA model fits the data reasonably well. Table 4-5b shows the standardized factor loadings as well as t-values in the holistic CFA model. All the factor loadings are significant at the

0.01 level with loadings near or above 0.70, which suggests convergent validity/unidimensionality.

4.4.3 Discriminant validity

Discriminant validity measures the extent to which scales developed to measure different constructs are indeed measuring different constructs. Following the method suggested by the literature (Garver and Mentzer 1999; O'Leary and Vokuka 1998), I tested for discriminant validity between the constructs by running two CFA models for each pair. In the first CFA model, the correlation between the constructs is free to vary. In the second, the correlation is fixed to a perfect correlation (1.0). If the two models show statistically significant chi square test results, there is discriminant validity (O'Leary-Kelly and Vokurka, 1998; Garver and Mentzer, 1999). I applied a Bonferroni correction to the original significance criteria (p-value <0.05) since I am performing a number of repeated tests (Byrne 1994, Kroes and Ghosh 2010). This correction leads to a significance criteria p-value <0 .00076. Table 4-5 shows the results of all the 66 pairs of chi-square difference tests, all of which show significance (p-value<.00076), indicating discriminant validity.

INSERT TABLE 4-5 HERE.

4.4.4 Reliability

It is important to ensure that the instrument is reliable. Reliability tests measure the extent to which a questionnaire or scale will repeatedly yield the same results (Flynn, et al., 1990). To test reliability, I used both the traditional reliability measures, such as Cronbach's Alpha, Spearman Brown (unequal-length), and Guttman Split-Half, and SEM construct reliability measures, such as construct reliability and variance extracted (Garver and Mentzer 1999).

From Table 4-6a, we could see that all the constructs' Cronbach's Alpha are higher than .70 (most are higher than .80), indicating reliable scales (Dunn, Seaker and Waller 1994, Garver and Mentzer 1999). In addition, all the scales have Spearman Brown coefficients higher than 0.70 and Guttman Split-Half scores higher than 0.60, except task interdependence, which has a Guttman Split-Half score slightly lower than 0.58. Table 4.6b shows the two SEM scale reliability measures for all the 12 constructs. All the constructs have SEM construct reliability scores higher than 0.70 and variance extraction scores higher than 0.50, indicating acceptable reliability levels (Garver and Mentzer 1999).

INSERT TABLE 4-6 HERE.

4.4.5 Non-response bias and common method bias

Non-respondents are a concern in survey research as they may indicate a bias among the sampled population away from those hypothesized. I attempted to minimize non-response bias through the use of advanced letters, follow-up phone calls, assurance of confidentiality, and incentives (Lambert and Harrington, 1990). Two procedures were used to test for the presence of non-response bias using two methods. First, I compare the early responses to our survey with the late responses to our survey, with the assumption that the late responders serving as a proxy for the non-responders (Armstrong and Overton, 1977). Labeled as "wave analysis", the approach compares parameter estimated between groups of respondents based on the timing of the receipt of their replies. If there is no significance in estimates between early and late respondents, then non-response bias is not a concern. The analysis was justified in this analysis since all respondents were notified of the survey in roughly the same time frame. However, some completed the survey several weeks following the original email/mail and phone call, indicating a possible reluctance in participation. I compared results from the first and the last 30 survey responses on all the 46 items composing the 12 main constructs. Table 4-7 shows that no significant differences between the two groups are identified.

In addition, I conducted t-tests on the 2010 sales figures and on number of employees between a random sample of 100 respondents and 100 non-respondents from our population pool. The company information for non-respondents (and any missing information for respondent firms) was gathered from Campustat and Hoovers. The t-tests did not indicate statistically significant differences between the respondents and non-respondents on either sales figures or number of employees. A representative of the findings is listed in Table 4-7.

INSERT TABLE 4-7 HERE

Common method bias raises the issue of deviation in survey responses as a result of having a common method for collection of data. The resultant is variance based on the method used as opposed to the constructs that the measures represent (Podsakoff, et al., 2003). An overestimation of effect size can result from increased correlations among the measures due to method variance (Doty and Glick, 1998). I attempted to minimize common method bias through separating the respondents answering dependent variables from those evaluating independent variables. In addition, I employed two data collection methods, on-line and mail surveys, to minimize the bias associated with one data collection method.

Nevertheless, checks for common method bias are still performed. Out of the 426 responses, 186 were completed online and 240 were completed on paper. T-tests comparing responses on all the items for the 12 constructs completed online with an equal random sample of those completed on paper showed no significant difference. Harman's Single Factor Test is employed to examine for common method bias. The test is conducted by loading all the items in a study into an exploratory factor analysis and examining the unrotated factor solution (Podsakoff et al., 2003). If the items load on a single factor, common method bias may be present. Using this approach, an exploratory factor analysis of the items composing the 12 main constructs in our study was conducted. The analysis found that items load into 12 factors with eigenvalues greater than 1.0, which is a strong indication that common method bias is not present in our sample.

4.5 Analytical strategy: Moderated and mediated structural equation modeling

Structural equation modeling (SEM) is employed as the statistical tool to test the conceptual model. SEM encourages confirmatory rather than exploratory modeling; thus, it is suited to the theory testing purpose of this study. Contrary to first generation statistical tools such as regression, SEM enables researchers to answer a set of interrelated research questions in a single, systematic, and comprehensive analysis by modeling the relationships among multiple independent and dependent constructs simultaneously . This capability for simultaneous analysis differs greatly from most first generation regression models such as linear regression, LOGIT, ANOVA, and MANOVA, which can analyze only one layer of linkages between independent and dependent variables at a time. The intricate causal networks enabled by SEM characterize real-world processes better than simple correlation-based models. Therefore, SEM is more suited for the mathematical modeling of complex processes, such as the inter-firm co-design processes studied here, to serve both theory and practice. The combined analysis of the measurement and structural models enables: (1) measurement errors of the observed variables to be analyzed as an integral part of the model, and (2) factor analysis to be combined in one operation with the hypotheses testing, both of which are important for the conceptual model proposed in this study. The result is a more rigorous analysis of the proposed research model and, very often, a better methodological assessment tool.

The distinction between formative and reflective measures is important because proper specifications of a measurement model are necessary before meaning can be assigned to the relationships implied in the structural model (Anderson and Gerbing 1988). I determine whether the constructs defined and measured in this study are reflective or formative following the three theoretical considerations (Coltman et al. 2008). Except technical and relational uncertainty, all the latent constructs are reflective. To be reflective, the latent construct should exist independent of the measures used (Consideration 1) and cause the indicators (Consideration 2), which are interchangeable (Consideration 3). All these three considerations do not apply to either technical or relational uncertainty. Both types of uncertainty do not exist as independent entities. Rather, they are composite measures.

Technical uncertainty is based on three dimensions of task interdependence, while relational uncertainty is formed with two dimensions of coordination efforts (reversely scaled) and idiosyncratic investments (reversely scaled) (violate consideration 1). Any change in any one of the dimensions causes a change in the uncertainty scores (violates consideration 2). Furthermore, the underlying dimensions for each type of uncertainty is not interchangeable, thus the inclusion or exclusion of one or more dimensions materially alter the content domain of the construct (violates consideration 3). Thus both technical and relational constructs are formative constructs. Specifically, their measurement models are spurious models according to Edwards and Bagozzi (2000)'s categorization. The reason is that each dimension of the two constructs is further a reflective latent construct. Due to the specification and estimation challenges faced by SEM models involving formative constructs (MacCallum and Browne 1993, Diamantopoulos and Winklhofer 2001, Diamantopoulos, 2006), the two uncertainty constructs are not specified as latent second-order formative constructs. Rather, a single item, using the average score of all the items composing all the underlying dimensions, is used for each of the uncertainty construct. This treatment also significantly reduces the number of items in the four latent interaction constructs created later for the moderating SEM models.

To measure the moderation effects, four latent interaction constructs were created following Little et al. (2006)'s four-step method. This method is straightforward and can be used across any SEM platform. This method is based in principle on the product-indicator approach but uses the orthogonalizing procedures described to create product indicators that are uncorrelated with the indicators of the main-effect constructs. Comparing with other methods for creating latent interaction constructs, this method is less technically demanding and provides reasonable estimates. The four steps are: (1) forming all possible products of the corresponding indicators of the two constructs involved in the interaction, (2) regressing each of the product indicators onto the set of indicators of the main-effect constructs, (3) replacing each product indicator with the corresponding regression residual, serving as the new orthogonal indicator for the corresponding latent interaction construct, and (4) correlating residuals of orthogonal product indicators sharing a common indicator. Following these steps, four latent interaction constructs: communication intensity * technical uncertainty (CITU), communication intensity * relational uncertainty (CIRU), goal congruence * technical uncertainty (GCTU), and goal congruence * relational uncertainty (GCRU). Each construct is composed by two, two, four and four items, respectively.

To test the full mediation effect of collaboration quality, I used the four-step Normal Theory Method developed by Baron and Kenny (1986). First, there must be a significant correlation between the predictor variable X and the dependent variable Y. Second, the predictor variable X must account for a significant proportion of the variance in the mediating variable M. Third, the mediator variable M must account for a significant proportion of variance in the dependent variable Y. Fourth, the association between the predictor variable X and the dependent variable Y must be significantly less after controlling for the variance shared between the mediator and dependent variable. Specifically, if the association between X and Y becomes insignificant after adding M to the model, the model is said to be a full mediation model. If the association between X and Y is still statistically significant, just at a lower scale, after adding M to the model, the mediation effect is said to be partial. According to Kenny et al. (1998), the first condition is not necessary. Frazier et al.

(2004) described several situations in which mediation may occur in the absence of a significant relationship between the predictor and dependent variable. Thus I only use the last three steps in the mediation analysis.

The fully specified SEM model is shown in Figure 4-1.

INSERT FIGURE 4-1 HERE.

Table 4-1 ANOVA Analysis Testing for Mean Differences Across Industries

		Sum of Squares	df	Mean Square	F	Sig.
PD	Between Groups	544.085	15	36.272	1.300	0.199
	Within Groups	10857.956	389	27.912		
	Total	11402.041	404			
PS	Between Groups	710.450	15	47.363	1.570	0.079
	Within Groups	11732.336	389	30.160		
	Total	12442.786	404			

Table 4-2 Measurements of the constructs

Constructs	Measurements	Literature
Communication Intensity	Please assess how people from your firm communicated with people from the supplier in the project: 1. Communication was frequent 2. Communication was intensive *Response set: 1, disagree, 5, agree.*	Hoegl and Wagner (2005), Takeishi (2001)
Task interdependency	"One firm" and "the other firm" mentioned below refer to either your firm or the supplier firm. Throughout the project, 1. People from one firm had to depend on people from the other firm to obtain the materials, people, or information needed to do their work 2. After people from one firm finished their part of the job, they had to rely on the other firm to perform the next steps in the process before the total task was completed 3. Very often one firm's job required that it check with the other firm while doing its major tasks *Response set: 1, disagree, 5, agree.*	Gresov (1989), Van de Ven and Ferry (1980)
Product complexity	1. The number of components in this product is much more than that in similar or substitute products 2. The product design required a higher number of interfaces than for similar or substitute products 3. The components for the product are more difficult to modularize than components for similar or substitute products 4. The level of expertise required for the design of the new product is high and more differentiated than for similar or substitute products *Response set: 1, disagree, 5, agree.*	Griffin (1993), Dooley and Van de Ven (1999), Dooley (2001), Fitzsimmons et al. (1991), Swink (1999) and Choi and Krause (2006), Oke et al. (2008)
Product technological novelty	Please assess the newness of the technologies to your company as perceived by the project group at the beginning of the project. 1. How new, on average, were the product modules? 2. How new was the product configuration ? 3. Overall, how new were the product technologies to be employed in this project? *Response set: 1, disagree, 5, agree.*	Tatiknoda and Rosenthal (2000)

Process Technological novelty	Please assess the newness of the technologies to your company as perceived by the project group at the beginning of the project. 1. How new, on average, were the individual manufacturing stages ? 2. How new was the process layout ? 3. Overall, how new were the manufacturing technologies to be employed with this project? *Response set: 1, disagree, 5, agree.*	Tatiknoda and Rosenthal (2000)
Goal congruence	Members from the buyer and supplier firms: 1. have goals that are in conflict with each other (reverse coded) 2. have compatible goals 3. support each other's objectives 4. felt it is highly likely to simultaneously realize goals of the two firms *Response set: 1, disagree, 5, agree.*	Jap (1999, 2001)
Coordination efforts	1. Our firm works with this supplier on joint projects tailed to our respective needs. 2. Our firm works with the supplier to exploit unique opportunities. 3. Both our firm and the supplier are looking for synergetic ways to do business together. *Response set: 1, disagree, 5, agree.*	Jap (2001)
Idiosyncratic investments	1. If our relationship with the supplier were to end, both firms would waste a lot of knowledge that's tailored to our relationship. 2. If either our firm or the supplier were to switch to a competitive buyer or vendor, it would lose a lot of the investments made in the present relationship. 3. Both our firm and the supplier have invested a great deal in building up our joint business *Response set: 1, disagree, 5, agree.*	Jap (2001)

Collaboration quality	Mutual supports Between the buyer and the supplier members . . . • 1. important ideas and information were exchanged openly. • 2. people adapted well to each other. • 3. the general atmosphere was cooperative. Communication quality The buyer and the supplier members were fully satisfied with . . . • 4. the timeliness in which information was made available. • 5. the accuracy of the information. Sufficiency of efforts The buyer and the supplier members. . . • 6. assumed full responsibility for achieving the project's objectives. • 7. fully contributed to carrying the project's workload. • 8. were fully committed to reaching the project objectives. Coordination • 9. The different job and work activities conducted by members from the two firms fit together very well. • 10. People from the two firms who had to work together did their jobs properly and efficiently. • 11. All related things and activities were well timed in the everyday routine of the project. • 12. The work assignments of the people from the two firms were well planned. Knowledge/skill-based contributions • 13. Strengths and weakness of members from our firm and the supplier are recognized. • 14. Members from both firms were contributing to the project in accordance with their specific potential. • 15. Imbalance of contributions from our firm and the supplier caused conflicts in the project. *Response set: 1, disagree, 5, agree.*	Hoegl and Wagner (2005), Hoegl and Gemuenden (2001), Littler et al. (1998), Ragatz et al. (2002), and Tjosvold (1984), Sivadas & Dwyer (2000)

Design Quality	1. The component design is of high quality. The component design fully complies with the specifications regarding … 2. dimensional integrity 3. durability 4. functionality 5. manufacturability 6. The component design fits to the target customers' needs. Please assess *the aggressiveness of project goals* for designing this product 1. The design quality goal for this product was very aggressive 2. The dimensional integrity goal for this product was very aggressive 3. The durability goal for this product was very aggressive 4. The functionality goal for this product was very aggressive 5. The manufacturability goal for this product was very aggressive 6. The target customers' needs are very difficult to satisfy *Response set: 1, disagree, 5, agree.*	Hoegl and Wagner (2005), Hoegl and Gemuenden 2001, Swink and Calantone (2004) and Takeishi (2001)
Design efficiency	Please evaluate the design process for this component. 1. Our budget goal for the project was fully achieved 2. The development cost for this product was kept low 3. The development cycle time goal for this component was fully achieved 4. The component design was completed on time Please assess the aggressiveness of project goals for designing this component 1. The development budget goal for this component was very aggressive 2. The development cycle time goal for this component was very aggressive *Response set: 1, disagree, 5, agree.*	Swink (1999),
Task Relevant Expertise	Project members (from both your firm and the supplier) 1. were knowledgeable about designing the product 2. were competent in designing the product 3. were expert in designing the product 4. were well trained in designing the product 5. were experienced in designing the product *Response set: 1, disagree, 5, agree.*	Netemeyer and Bearden (1992)

Table 4-3 Survey Response Summary

	Online				Hard copy/Mail			
	Part I	Part II	Contacted	Response Rate	Part I	Part II	Contacted	Response Rate
U.S.	224	186	2000	9.3%	28	28	45	62.2%
China	-	-	-	-	315	212	580	36.6%
Total	224	186	2000	9.3%	343	240	625	38.4%
Response Rate	16.23%							

Table 4-4a Measurement invariance results comparing the U.S. and China samples

Model	x^2	df	RMSEA	NFI	NNFI	CFI			p-value
Configural Invariance	4280.13	2786	0.045	0.89	0.96	0.96	-	-	-
Metric Invariance	4329.27	2842	0.044	0.89	0.96	0.96	49.14	56	0.72
Full Invariance	4405.07	2908	0.044	0.89	0.96	0.96	75.8	66	0.19

Table 4-4b Measurement invariance results comparing the online and mail samples

Model	x^2	df	RMSEA	NFI	NNFI	CFI			P-Value
Configural Invariance	4404.73	2786	0.05	0.90	0.96	0.96	-	-	-
Metric Invariance	4415.90	2842	0.049	0.90	0.96	0.96	11.23	55	1
Full Invariance	4426.26	2908	0.048	0.90	0.96	0.96	10.36	66	1

Table 4-5 Chi-Square Difference Tests of Discriminant Validity

Factor Pairs	Constrained (df)		(df)	Significance
Communication intensity (CI) with				
Goal congruence (GC)	3006.66	(1365)	173.6(1)	<0.0001
Task interdependence (TI)	2998.11	(1365)	165.05 (1)	<0.0001
Collaboration quality (CQ)	2990.14	(1365)	157.08 (1)	<0.0001
Design quality (DQ)	3014.49	(1365)	181.43 (1)	<0.0001
Design efficiency (PE)	3009.54	(1365)	176.48 (1)	<0.0001
Product complexity (PC)	3036.45	(1365)	203.39 (1)	<0.0001
Product technological novelty (PDTN)	3010.98	(1365)	177.92 (1)	<0.0001
Process technological novelty (PSTN)	3027.88	(1365)	194.82 (1)	<0.0001
Coordination efforts (CE)	3002.40	(1365)	169.34 (1)	<0.0001
Idiosyncratic investments (II)	2967.13	(1365)	134.07 (1)	<0.0001
Task relevant expertise (TRE)	3078.95	(1365)	245.89 (1)	<0.0001
Goal congruence (GC) with				
TI	3074.03	(1365)	240.97 (1)	<0.0001
CQ	3071.82	(1365)	238.76 (1)	<0.0001
DQ	3084.12	(1365)	251.06 (1)	<0.0001
PE	3082.85	(1365)	249.79 (1)	<0.0001
PC	3074.81	(1365)	241.75 (1)	<0.0001
PDTN	3100.93	(1365)	267.87 (1)	<0.0001
PSTN	3605.38	(1365)	772.32 (1)	<0.0001
CE	3077.86	(1365)	244.8 (1)	<0.0001
II	3063.38	(1365)	230.32 (1)	<0.0001
TRE	3074.75	(1365)	241.69 (1)	<0.0001
Task interdependence (TI) with				
CQ	3071.82	(1365)	238.76 (1)	<0.0001
DQ	3084.12	(1365)	251.06 (1)	<0.0001
PE	3082.85	(1365)	249.79 (1)	<0.0001
PC	3074.81	(1365)	241.75 (1)	<0.0001
PDTN	3100.93	(1365)	267.87 (1)	<0.0001
PSTN	3605.38	(1365)	772.32 (1)	<0.0001
CE	3077.86	(1365)	244.8 (1)	<0.0001
II	3063.38	(1365)	230.32 (1)	<0.0001
TRE	3074.06	(1365)	241 (1)	<0.0001
Collaboration quality (CQ) with				
DQ	4788.33	(1365)	1955.27(1)	<0.0001
PE	3081.44	(1365)	248.38 (1)	<0.0001
PC	3851.53	(1365)	1018.47 (1)	<0.0001
PDTN	3213.33	(1365)	380.27 (1)	<0.0001
PSTN	3433.76	(1365)	600.7 (1)	<0.0001
CE	3151.81	(1365)	318.75 (1)	<0.0001
II	3331.17	(1365)	498.11 (1)	<0.0001
TRE	4297.27	(1365)	1464.21 (1)	<0.0001
Design quality (DQ) with				

PE	2937.87	(1365)	104.81 (1)	<0.0001
PC	3492.85	(1365)	659.79 (1)	<0.0001
PDTN	3261.74	(1365)	428.68 (1)	<0.0001
PSTN	4665.53	(1365)	1882.47 (1)	<0.0001
CE	3178.69	(1365)	345.63 (1)	<0.0001
II	3304.02	(1365)	470.96 (1)	<0.0001
TRE	4281.38	(1365)	1448.32 (1)	<0.0001
Design efficiency (PE) with				
PC	3215.39	(1365)	382.33 (1)	<0.0001
PDTN	3088.60	(1365)	255.54 (1)	<0.0001
PSTN	3259.93	(1365)	426.87 (1)	<0.0001
CE	3125.07	(1365)	292.01 (1)	<0.0001
II	3091.37	(1365)	258.31 (1)	<0.0001
TRE	3103.15	(1365)	270.09 (1)	<0.0001
Product complexity (PC) with				
PDTN	3155.31	(1365)	322.25 (1)	<0.0001
PSTN	3324.85	(1365)	491.79 (1)	<0.0001
CE	3162.08	(1365)	329.08 (1)	<0.0001
II	3316.18	(1365)	483.12 (1)	<0.0001
TRE	3568.59	(1365)	735.53 (1)	<0.0001
Product tech. novelty (PDTN) with				
PSTN	3056.12	(1365)	223.06 (1)	<0.0001
CE	3217.64	(1365)	384.58 (1)	<0.0001
II	3210.70	(1365)	377.64 (1)	<0.0001
TRE	3330.21	(1365)	497.15 (1)	<0.0001
Process tech. novelty (PSTN) with				
CE	3198.45	(1365)	365.39 (1)	<0.0001
II	3327.46	(1365)	494.4 (1)	<0.0001
TRE	3530.22	(1365)	697.16 (1)	<0.0001
Coordination efforts (CE) with				
II	3028.49	(1365)	195.48 (1)	<0.0001
TRE	3304.08	(1365)	471.02 (1)	<0.0001
Idiosyncratic investment (II) with				
TRE	3367.31	(1365)	534.25 (1)	<0.0001

Table 4-6a Traditional reliability measures

Constructs	Reliability Coefficients		
	Cronbach's Alpha	Spearman Brown	Guttman Split-Half
Communication intensity	0.74	0.75	0.60
Goal congruence	0.83	0.88	0.78
Task interdependence	0.71	0.74	0.58
Collaboration quality	0.94	0.97	0.93
Design quality	0.92	0.93	0.88
Design efficiency	0.91	0.96	0.92
Product complexity	0.83	0.85	0.75
Product technological novelty	0.795	0.788	0.677
Process technological novelty	0.863	0.865	0.771
Coordination efforts	0.77	0.78	0.63
Idiosyncratic investments	0.83	0.85	0.73
Task relevant expertise	0.894	0.854	0.820

Table 4-6b SEM reliability measures

Construct/items	Construct Reliability	Variance Extracted	Standardized Coefficient	t-value	R-square	measurement error
Communication Intensity	0.75	0.60				
ci1			0.76	14.86	0.57	0.42
ci2			0.79	15.40	0.62	0.38
Goal Congruence	0.82	0.54				
gc1			0.53	10.99	0.28	0.72
gc2			0.74	16.92	0.55	0.45
gc3			0.88	21.51	0.78	0.23
gc4			0.75	17.26	0.57	0.44
Task Interdependence	0.72	0.46				
ti1			0.71	13.55	0.50	0.50
ti2			0.75	14.32	0.57	0.44
ti3			0.56	10.73	0.31	0.69
Collaboration Quality	0.95	0.54				
cq1			0.71	16.42	0.50	0.50
cq2			0.77	18.47	0.59	0.41
cq3			0.75	17.71	0.56	0.44
cq4			0.76	18.01	0.57	0.42
cq5			0.77	18.63	0.60	0.41
cq6			0.76	18.31	0.58	0.42
cq7			0.75	17.85	0.56	0.44
cq8			0.78	19.01	0.61	0.39
cq9			0.61	13.45	0.37	0.63
cq10			0.73	17.32	0.54	0.47
cq11			0.47	9.98	0.22	0.78
cq12			0.79	17.17	0.62	0.38
cq13			0.83	20.72	0.69	0.31
cq14			0.72	16.79	0.52	0.48
cq15			0.76	18.18	0.58	0.42
Product Complexity	0.84	0.57				
pc1			0.70	15.65	0.49	0.51
pc2			0.87	21.15	0.76	0.24
pc3			0.83	19.55	0.68	0.31
pc4			0.57	12.13	0.33	0.68
Product Technology Novelty	0.80	0.57				
tn1			0.79	17.46	0.62	0.38
tn2			0.73	15.85	0.53	0.47
tn3			0.74	16.25	0.55	0.45

Process Technology Novelty	0.86	0.68				
tn4			0.83	19.80	0.69	0.31
tn5			0.80	18.63	0.63	0.36
tn6			0.84	20.09	0.70	0.29
Coordination Efforts	0.78	0.54				
ce1			0.70	14.61	0.48	0.51
ce2			0.74	15.72	0.55	0.45
ce3			0.76	16.22	0.58	0.42
Idiosyncratic Investment	0.83	0.63				
ii1			0.69	15.21	0.47	0.52
ii2			0.84	19.96	0.71	0.29
ii3			0.84	19.71	0.70	0.29
Design Quality	0.92	0.67				
dq1			0.84	21.19	0.71	0.29
dq2			0.84	21.05	0.70	0.29
dq3			0.86	21.80	0.74	0.26
dq4			0.86	22.06	0.75	0.26
dq5			0.80	19.56	0.64	0.36
dq6			0.68	15.54	0.46	0.54
Design efficiency	0.88	0.65				
pe1			0.74	16.29	0.54	0.45
pe2			0.74	16.44	0.55	0.45
pe3			0.87	20.31	0.76	0.24
pe4			0.86	19.79	0.74	0.26
Task Relevant Expertise	0.90	0.66				
tre1			0.89	23.17	0.79	0.21
tre2			0.94	25.17	0.88	0.12
tre3			0.82	20.35	0.67	0.33
tre4			0.82	20.49	0.68	0.33
tre5			0.52	11.26	0.27	0.73

Table 4-7 Tests of Non-Response Bias

Abbreviation	Item Description*	*p*-value
Early v. Late Respondents (n=30x2)		
CI-1	Communication intensity – intensive communication	0.273
TI-2	Task interdependence – sequential dependence	0.712
GC-2	Goal congruence – goal compatibility	
CQ-10	Collaboration quality – potential based contributions	0.119
PD-3	Design quality – durability (achievement * aggressiveness)	0.299
PS-4	Design efficiency – on time completion	0.142
PC-1	Product complexity – a large number of components	0.467
PDTN-1	Product technological novelty – product modules newness	0.357
PSTN-2	Process technological novelty – process layout newness	0.301
CE-1	Coordination efforts – joints projects	0.948
II-2	Idiosyncratic investments – loss of investment if the relationship breaks up	0.805
TRE-4	Task relevant expertise – trained-not trained	0824
Respondents v. Non-Respondents (n=100x2)		
SALES	Sales	0.449
EMPL	Employees	0.582

* The list is a sample of items from the complete survey are listed

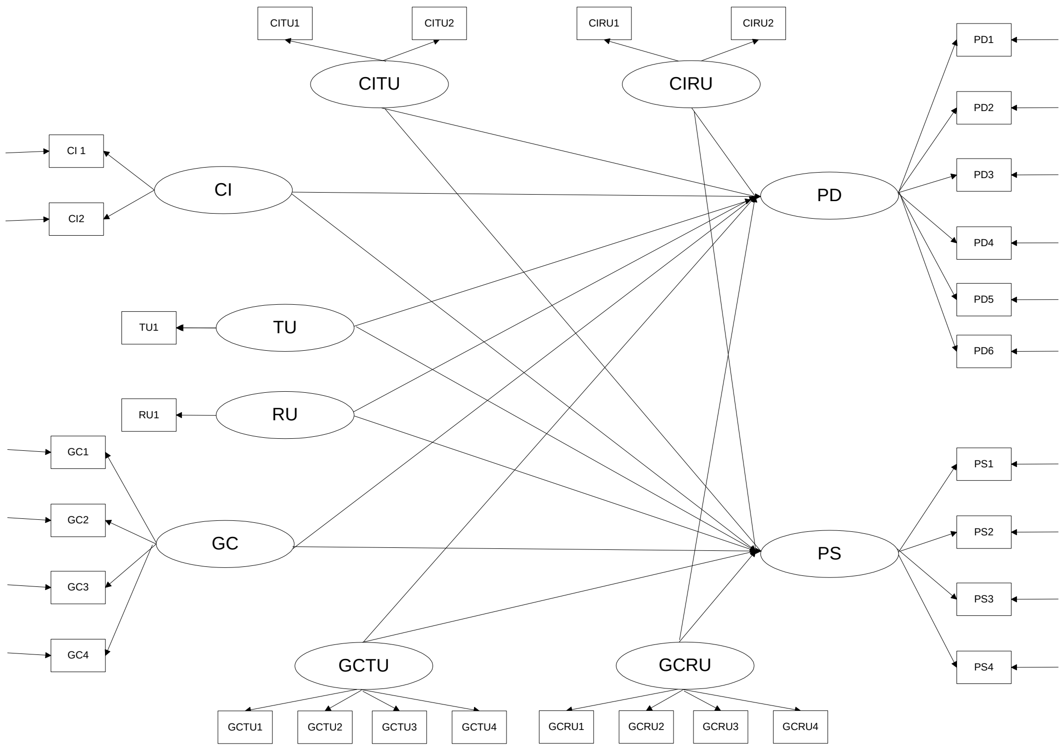


Figure 4-1 A fully specified moderation SEM graph

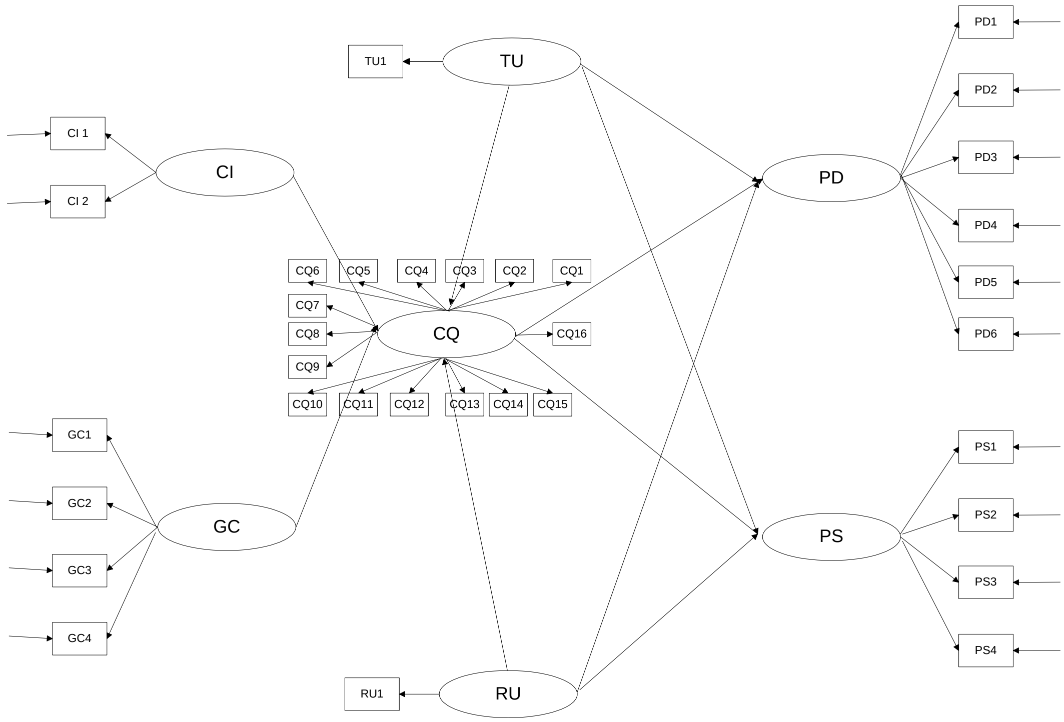


Figure 4-2 A fully specified mediation SEM graph

5 A SUMMARY OF RESULTS

This chapter provides a summary of the findings. I start with reviewing the descriptive statistics of the collected data. I then explain the significant and non-significant results, starting with the direct effects of communication intensity and goal structure, followed by moderation effects of technical and relational uncertainty, and finally the mediation effect of collaboration quality. It should be noted that the explanations in this chapter refer to a multitude of tables and figures that are included at the end of the chapter. As such, I suggest for the reader to review the text and tables in tandem for a better grasp of the discussion.

5.1 Descriptive statistics

Table 5-1 show sample demographics of the full data set, the U. S. dataset and the China dataset. Although the complete sample crosses 16 industries, four of them, computer and electronic product manufacturing, electronic equipment, appliance and component manufacturing, transportation equipment manufacturing and medical equipment manufacturing, account for 64.3% of the combined sample. The two sub-samples, one from the U. S. and one from China, do not differ significantly in the industry distribution. A t-test comparing the U. S. and the China dataset shows no significant difference on industry distribution across the two samples at a .05 level (p-value=0.978341). Table 5-1b, c and d show sample distributions on firm size (number of employees), sales (dollars) and age (years). The two sub-samples show slight differences in the three distributions. The U.S. sample has a higher percentage of big firms (more than 5000 employees) and older firms (more than 20 years since firm's establishment) than the China sample. Regarding the sales distribution, the China sample is composed more by firms with sales higher than 5M, while the U.S. sample is composed more by smaller firms (sales less than 5M). The sample demographics show that the sample is quite comprehensive, crossing multiple industries and involving firms of different sizes and ages, thus ensuring the external generalizability of results from this study.

INSERT TABLE 5-1 HERE.

Descriptive statistics (mean, standard deviation, correlations, etc.) for the combined sample are shown in Table 5-2. Average and standard deviation figures show all the scales have an average near the middle of the scale and have responses across the range of the scale. For instance, the two performance measures design quality and design efficiency each of which is an average summed product of multiple 5-scale Likert items (goal achievement and goal aggressiveness), have means around 11 and standard deviations around 5. These are expected because the theoretical middle point of both scales should be 9 (3*3). The distribution of performance measures also show that the sample covers both projects that perform very well and those that do not meet expectation. All other constructs have means around the middle point of the 5-point Likert scales, 3, and enough variation (standard deviations all above .60). All the items have skewness and kurtosis scores within (+/-2.99) and most are close to zero, indicating the acceptability of the normal distribution assumption under the SEM program (see Appendix B-1 for details).

Several variables are significantly correlated with the two performance constructs. Both communication intensity and goal congruence are significantly correlated with both design quality and design efficiency. Some sources of technical uncertainty are significantly associated with performance. Product technology newness is significantly associated with both design quality and design efficiency, surprisingly, in a positive way, while process technology newness is negatively associated with design efficiency without a significant relationship with design quality. Neither product complexity nor task interdependence is significantly associated with performance. Coordination efforts and idiosyncratic investments, two ways to reduce relational uncertainty, are significantly positively associated with both design quality and design efficiency. The control variable, task relevant expertise, is not significantly associated with project performance.

INSERT TABLE 5-2 HERE.

5.2 Results

5.2.1 The moderation model: roles of technical and relational uncertainty

Figure 5-1 shows the SEM analysis results for the moderation model. In the SEM model, in addition to the four main constructs, communication intensity, goal congruence, technical uncertainty, relational uncertainty, and the four interaction latent constructs, five control variables are added to the model to control for their effects on both design quality and design efficiency. Firm size is a latent variable, measured by two items, the natural log of the number of employees and the natural log of firm sales. Firm age is a single-item construct, measured by the natural log of the number of years since the firm's establishment. Country is a binary (1-2) variable, where 1 representing data collected from China and 2 representing those from the U.S. Supplier involvement timing is a single item construct, where 1 representing supplier involvement at the idea generation stage, 2 for those at the model building stage and 3 for those at the prototype building or later stages. Finally, the latent construct Task Relevant Expertise is measured by 5 items.

INSERT FIGURE 5-1 HERE.

Fit indices show the structural model fits the data well. Chi-square (df=598) is 1445.20, significant better than that of the independent model whose Chi-square (df=780) is 14506.04. RMSEA is .049, with a p-value for Test of Close fit (RMSEA<.05) of .70, indicating a good fit to the data. Similarly, NNFI, CFI and IFI are all above .90, meeting expectations. SRMR is .070, below the threshold of .80 for acceptable fits between the model and the data. In addition, the structural model explains a significant proportion of variances in the two dependent variables (R-squares are 26% for design quality and 18% for design efficiency).

The significance of the impact of the fit between communication intensity and two types of uncertainties (hypotheses 1a, 1b, 2a and 2b) on project performance are tested by examining the significance of the paths from the four interaction constructs onto the two performance constructs. The positive effect of the communication-uncertainty fit on project performance is supported by a positive significant interaction effect. From Figure 5-1, we could see that all the four interaction effects on the left-half of the figure are positive and significant at, at least, a .05 level, thus showing supports for hypotheses 1a, 1b, 2a and 2b.

Hypotheses 3a and 3b propose that goal congruence has significant main effects on design quality and design efficiency, respectively. These two hypotheses are tested by testing the significance of the pure main effects of goal congruence on performance through removing the two interaction terms that involve goal congruence from the structural model: goal congruence*technical uncertainty and goal congruence*relational uncertainty. The model without these two interaction terms still fit the data well (RMSEA=.049, NNFI=.92, CFI=.92, IFI=.92, SRMR=.071). The standardized path coefficients from goal congruence to design quality and design efficiency are .15 and .19 respectively, both with p-values less than .01. Thus hypotheses 3a and 3b are fully supported.

Hypotheses 4a, 4b, 5a and 5b propose that technical uncertainty negatively moderate and relational uncertainty positively moderate the paths from goal congruence to both types of project performance. They are tested by examining the significance of paths from the two interactions: goal congruence*technical uncertainty and goal congruence*relational uncertainty, to performance. SEM results show that technical uncertainty negatively moderate the paths from goal congruence to design quality (p-value<.01) and design efficiency (p-value<.05), thus supporting hypotheses 4a and 4b. However, relational uncertainty does not significantly moderate the goal congruence-performance relationship, thus failing to support hypotheses 5a and 5b.

To further triangulate the findings from the SEM analysis, I used hierarchical regression to test the same set of hypotheses. All the latent constructs were measured by averaged item scores. To minimize multi-collinearity problem, common in regression models involving interaction terms, the four main independent variables (communication intensity, goal congruence, technical uncertainty, and relational uncertainty) were centered (Aiken and West 1991). Control variables were entered into the model first (model 1), followed by main effects (model 2), and lastly the interactions (model 3). Regression coefficients shown in Table 5-3 are all standardized solutions, thus comparable with SEM results. Table 5-3 shows results from the hierarchical regression analysis.

Table 5-4 shows a comparison of hypotheses testing results using the two analysis methods. Most of the hypotheses are supported by results from both methods, increasing the credibility of the hypotheses testing results. Furthermore, the standardized path (regression) coefficients obtained using the two methods are also quite similar. The regression analysis failed to find supports for hypotheses 1b and 4b, both of which are associated with the moderating effects of technical uncertainty in the design efficiency model. Differences in results may be attributed to several reasons: (1) there is no measurement error in the regression analysis, causing a loss of statistical power in identifying significant relationships (e.g., the R-squares are lower in the regression analysis, compared to those in the SEM analysis), (2) firm size (number of employees) and sales are two items measuring a single latent construct in the SEM analysis, while they are two separate variables in the regression analysis.

Further interpretation of the interaction effects is accomplished through examination of the interaction plots. The interactions are plotted using the standardized path loadings from the SEM model by following a slightly modified interaction analysis procedure commonly used for multiple regression (Aiken and West, 1991). Figure 5-2 shows all the 2-way interaction plots. In each plot, the dotted blue line represents a high level of uncertainty (one standard deviation above the mean level of uncertainty), while the red solid line represents a low level of uncertainty (one standard deviation below the mean level of uncertainty). Except the two variables involved in the interaction, all the other variables are kept at their mean levels. In each plot, the level of either communication intensity or goal congruence is measured on the x-axis, ranging from a very low level (three standard deviations below the mean level of emphasis) to a very high level (three standard deviations above the mean level of emphasis.) Project performance is measured on the y-axis. The units on both axes are shown in standard deviations around the mean values. When interpreting these plots, the moderating effect of either type of uncertainty is visualized by the difference in the slopes of the two lines.

Plots (a), (b), (c) and (d) show the effects of communication-uncertainty fit on project performance. The four plots share the same pattern: project performance is higher when there is a fit between the communication intensity level and the uncertainty level. For instance, in plot (a), design quality is around .6 standard deviation above the mean level when communication intensity is 3 times standard deviation above the mean in the case of high technical uncertainty, higher than a level of around .4 standard deviation lower than the mean level in the low technical uncertainty case. This suggests that intensive communication is more effective in increasing design quality when technical uncertainty is high. Similarly, design quality is around .2 times standard deviation above the mean level when communication is not intensive at all (around 3 standard deviations below the mean level) in the low technical uncertainty case, compared to a performance level of .4 standard deviations lower below the mean in the high technical uncertainty case. This suggests that a low communication level leads to a better design when there is not much technical uncertainty, compared to when technical uncertainty is high.

Another observation from comparing these first four plots is that the positive impact of the communication-uncertainty fit varies across the level of communication intensity.

Specifically, the positive impact of the communication-uncertainty fit on performance is higher when communication intensity is towards the lower end for plot (b), (c) and (d), but not for plot (a). The misfit situation in a low communication intensity case simply means under-communication: a situation where the level of communication is not enough to deal with the uncertainty level. Similarly, over-communication, the other type of misfit, is the situation where there is too much communication given the low uncertainty level. Thus this observation implies (1) under-communication, compared to over-communication, has a greater negative impacts on design quality when the communication is used to manage relational uncertainty (plot b); and (2) under-communication, compared to over-communication, has a greater negative impacts on design efficiency when the communication is used to manage either technical uncertainty (plot c) or relational uncertainty (plot d). In contrast to plot (b), (c) and (d), plot (a) shows that over-communication is more harmful in terms of lowering design quality when the communication is used to manage technical uncertainty.

Plots (e), (f), (i) and (j) show the moderating effects of technical and relational uncertainty on paths from goal congruence to project performance. Significant differences in slopes of the blue dotted and the red solid lines verify the moderating effects. Only plot (e) and (i) show such significant differences in slopes. Specifically, a high level of goal congruence leads to a worse design as well as a less efficient process in the high technical uncertainty case, compared to the low technical uncertainty case. In contrast to technical uncertainty, relational uncertainty does not significantly change the slope of the two lines (plot f and j).

INSERT FIGURE 5-2 HERE.

In addition to those results directly related with hypotheses testing, the two methods generate some other similar results. For instance, both analyses found that firm age is positively associated with performance, suggesting older firms are more likely to succeed in collaborative NPD projects involving suppliers. According to both analyses, the United States samples performed significantly better than the China sample in both design quality and design efficiency (the Country variable is significant in both analyses). Technology uncertainty is not significantly associated with project performance, while relational uncertainty is negatively associated with both types of project performance. Both analyses identify significant positive relationships between supplier involvement timing and project performance. Surprisingly, task relevant expertise is consistently found to be not significantly associated with any performance measure.

5.2.2 The mediation model: the role of collaboration quality

Several SEM structural equations are run to in several steps to test hypotheses from H6a to H9b:

1. Two structural equations, one for design quality and one for design efficiency, are run to test main effects of communication intensity and goal congruence on project performance, after controlling for technical and relational uncertainty as well as the five control variables (hypotheses 7 and 8).

2. Collaboration quality is added to the two structural equations to test its effects on project performance (hypotheses H6a and 6b).

3. One more structural equation with collaboration quality as the dependent variable, predicted by communication intensity, goal congruence, technical and relational uncertainty, and the five control variables, is added to the existing equations.

4. Standardized path coefficients from communication intensity and goal congruence to performance are compared before and after adding collaboration quality to the model to test the mediation effects of collaboration quality (Hypotheses 9a and 9b).

Table 5-5 shows results from running the above equations. Two SEM models were run: Model 1 includes the two structural equations with performance as dependent variables and without collaboration quality as an independent variable; Model 2 adds collaboration quality to both structural equations in Model 1 as independent variables, in addition to adding a third structural equation with collaboration quality as the dependent variable. Standardized path coefficients as well as fit indices of the two models are shown in Table 5-5. Fit indices show that both models fit the data reasonably well.

Following Baron and Kenny (1986)'s three steps (step 2, 3 and 4 as mentioned in the end of section 4), I first checked whether communication intensity and goal congruence explain variance in collaboration quality, the mediator, in a significantly way. The last column in table 5-5 shows that path coefficients for both communication intensity (.21***) and goal congruence (.70***) are significant, at a 0.001 level, in the model predicting collaboration quality, after controlling for effects of other variables. Thus hypotheses 7 and 8 are supported. In step 3, the paths from collaboration quality to performance need to be checked for significance. From the third and fourth columns, we could see that collaboration quality is significantly, at a 0.001 level, positively associated with both design quality and design efficiency, thus supporting hypotheses 6a and 6b. The last step is to check whether standardized path coefficients from communication intensity and goal congruence to performance decrease when the mediator (collaboration quality) is added to the models. Comparing the coefficients for communication intensity and goal congruence in Table 5-5, we can see that communication intensity's coefficients stay as insignificant for both design quality and design efficiency when collaboration quality is added to the two models, while goal congruence's coefficients change from being significant to being insignificant (.17*** to .04 for design quality and .20*** to .08 for design efficiency). Thus goal congruence's positive effects on project performance are fully mediated by collaboration quality. Thus hypotheses 9a and 9b are partially supported.

To triangulate results obtained in the SEM analysis, hierarchical regression is again used to test the mediation effect of collaboration quality. Each latent construct used in the SEM analysis is measured by an average of all the items' scores for the construct. In model 1, only the six control variables are entered into the model. Main effects of communication intensity, goal congruence, technical uncertainty and relational uncertainty are added to the model in model 2. In model 3, collaboration quality is added as an independent variable. In a separate regression analysis (Model 4), collaboration quality is the dependent variable, predicted by communication intensity, goal congruence, technical uncertainty and relational uncertainty, after controlling for the six same control variables. Table 5-6 shows standardized regression coefficients as well as fit indices of the regression analysis.

In model 4, we could see that both communication intensity and goal congruence are significantly associated with DQ, which is found to be a significant predictor of both design quality and design efficiency in model 3. Finally, communication intensity's regression coefficients decrease from .04 to -.00 for design quality and .07 to .03 for design efficiency, although all being insignificant. Similarly, goal congruence's standardized regression coefficients decrease from .14 (significant at a .001 level) to .02(not significant) for design quality and from .18 (significant at a .001 level) to .05 (not significant) for design efficiency after collaboration quality is added to the model. Thus we could obtain the same conclusion: both communication intensity and goal congruence's positive effects on project performance are mediated by collaboration quality. Furthermore, goal congruence's effects are fully mediated by collaboration quality.

INSERT TABLE 5-6 HERE.

Table 5-1a Sample Demographics-Industry distribution

Industry sectors	Combined Sample Frequency	Combined Sample Percentage	U.S. Sample Frequency	U.S. Sample Percentage	China Sample Frequency	China Sample Percentage
311 Food Manufacturing	2	0.5	1	0.5	1	0.5
313 Textile Mills	1	0.2	0	0	1	0.5
321 Wood Product Manufacturing	2	0.5	2	0.9	0	0
323 Printing and Related Support Activities	1	0.2	1	0.5	0	0
324 Petroleum and Coal Products Manufacturing	1	0.2	1	0.5	0	0
326 Plastics and Rubber Products Manufacturing	3	0.7	2	0.9	1	0.5
327 Nonmetallic Mineral Product Manufacturing	2	0.5	1	0.5	1	0.5
331 Primary Metal Manufacturing	1	0.2	0	0	1	0.5
332 Fabricated Metal Product Manufacturing	14	3.3	8	3.7	6	2.8
333 Machinery Manufacturing	31	7.5	12	5.6	19	9.0
334 Computer and Electronic Product Manufacturing	104	24.4	63	29.4	41	19.3
335 Electrical Equipment, Appliance, and Component Manufacturing	71	16.7	35	16.4	36	17
336 Transportation Equipment Manufacturing	41	9.6	7	3.3	34	16
337 Furniture and	5	1.2	4	1.9	1	0.5

Related Product Manufacturing						
3391 Medical Equipment and Supplies Manufacturing	58	13.6	35	16.4	23	11.3
3399 Other Miscellaneous Manufacturing	68	16	33	15.4	35	16.5
Missing values	21	4.9	9	4.2	12	5.7
Total	426	100	214	100	212	100

Table 5-1b Sample demographics-firm size distribution

	Combined Sample		U.S. Sample		China Sample	
Firm size (# of Employees)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
0-100	91	21.36	51	23.83	40	18.97
101-300	76	17.84	40	18.69	36	16.98
301-1000	67	15.73	25	11.68	42	19.81
1001-5000	77	18.08	32	14.95	45	21.23
Above 5001	97	22.77	61	28.50	36	16.98
Missing values	18	4.23	5	2.34	13	6.13
Total	426	100	214	100	212	100

Table 5-1c Sample demographics-firm sales distribution

	Combined Sample		U.S. Sample		China Sample	
Firm sale ($)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
<=2.5 M	119	27.93	78	36.45	41	19.34
2.5 M-5M	115	27	69	32.24	46	21.70
5M-40M	74	17.37	22	10.28	52	24.53
>40M	81	19.01	35	16.36	46	21.70
Missing values	37	8.69	10	4.67	27	12.74
Total	426	100	214	100	212	100

Table 5-1d Sample demographics-firm age distribution

	Combined Sample		U.S. Sample		China Sample	
Firm age (Years)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
<=10	78	18.31	36	16.82	42	19.81
11-15	59	13.85	17	7.94	42	19.81
16-20	58	13.62	14	6.54	44	20.75
21-50	107	25.12	70	32.71	37	17.45
Above 50	105	24.65	72	33.64	33	15.57
Missing values	19	4.46	5	2.34	14	6.60
Total	426	100	214	100	212	100

Table 5-2 Constructs descriptive statistics

		Mean	S.d	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Communication intensity	3.81	0.94	1.00													
2	Task interdependency	3.76	0.90	0.29**	1.00												
3	Goal congruence	3.94	0.87	0.28**	-0.01	1.00											
4	Collaboration quality	3.67	0.69	0.38**	0.09	0.75**	1.00										
5	Design quality	12.83	5.35	0.26**	0.09	0.21**	0.29**	1.00									
6	Design efficiency	11.36	5.53	0.24**	-0.10	0.24**	0.33**	0.75**	1.00								
7	Product complexity	3.09	1.03	0.02	-0.05	-0.04	-0.08	-0.01	-0.05	1.00							
8	Product technological novelty	3.23	0.91	0.23**	-0.06	0.10	0.18**	0.17**	0.19**	0.37**	1.00						
9	Process technological novelty	2.79	0.99	0.06	-0.01	0.08	0.07	-0.04	-0.11*	0.39**	0.58**	1.00					
10	Coordination efforts	3.61	1.04	0.28**	-0.03	0.19**	0.22**	0.23**	0.15**	0.14*	0.10	-0.05	1.00				
11	Idiosyncratic investments	3.13	1.12	0.50**	0.23**	0.14**	0.08	0.26**	0.17**	0.20**	0.17**	0.12**	0.56**	1.00			
12	Task relevant expertise	3.98	0.86	0.05	0.01	0.04	0.02	-0.02	-0.04	-0.04	-0.06	-0.04	0.00	-0.03	1.00		
13	Technical uncertainty	3.21	0.61	0.09**	0.22**	-0.01	0.03	0.05**	0.00	0.52**	0.47**	0.49**	0.02	0.16**	-0.03	1.00	
14	Relational uncertainty	2.63	0.92	-0.39**	-0.06*	-0.08**	-0.21**	-0.23**	-0.16**	-0.16**	-0.08**	-0.09**	-0.85**	-0.86**	0.04	-0.09**	1.00

Table 5-3 Hierarchical regression analysis results

Variables	Design Quality			Design efficiency		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Intercept	***	***	***	***	***	***
Firm age (log)	.23***	.24***	.23***	.20***	.20***	.20***
Firm size (log)	-.01	-.03	.01	.05	.03	.04
Firm sales (log)	-.19**	-.17*	-.19**	-.16*	$-.13^{\psi}$	$-.13^{\psi}$
Country	.22***	.20***	.19***	.16***	.14**	.13**
Supplier involvement timing	.05	.14**	.13**	.05	.10**	.10**
Task relevant expertise	-.01	-.03	.02	-.02	-.04	-.04
Communication Intensity (CI)		.04	.02		.07	.03
Goal congruence (GC)		.14**	.12**		.18***	.16***
Technical uncertainty (TU)		.07	.07		-.03	-.02
Relational uncertainty (RU)		-.23***	-.23***		-.12*	-.13*
CI*TU			.09*			.04
CI*RU			.09*			.15**
GC*TU			-.11*			-.03
GC*RU			-.03			-.04
Adjusted R-square	.14	.23	.24	.09	.15	.16
R-square change	.15	.09	.02	.11	.06	.02
Significance of F statistics	***	***	***	***	***	***
Significance of F change	***	***	*	***	***	*

$^{\psi}$ p<0.10, *p<0.05, **p<0.01,***p<0.001, n=426

Table 5-4 A comparison of SEM and hierarchical regression results

Hypotheses	Supported by SEM	Supported by Regression
H1a: Communication intensity (CI)*Technical uncertainty (TU)→Design quality (DQ)	✔(.13)	✔(.09)
H1b: CI*TU→Design efficiency (DE)	✔(.11)	
H2a: CI*Relational uncertainty (RU)→DQ	✔(.08)	✔(.09)
H2b: CI*RU→DE	✔(.13)	✔(.15)
H3a: Goal congruence (GC)-DQ	✔(.16)	✔(.12)
H3b: GC-DE	✔(.20)	✔(.16)
H4a: GC*TU→DQ	✔(-.13)	✔(-.11)
H4b: GC*TU→DE	✔(-.09)	
H5a:GC*RU→DQ		
H5b:GC*RU→DE		

Numbers in the parentheses are standardized path (regression) coefficients.

Table 5-5 SEM mediation analysis results

	Design Quality		Design efficiency		CQ
	No CQ	With CQ	No CQ	With CQ	
	Model 1	Model 2	Model 1	Model 2	Model 2
Communication intensity	.028	.01	.06	.02	.21***
Goal congruence	.17***	.04	.20***	.08	.70***
Technical uncertainty	.08	.07	.06	.06	.03
Relational uncertainty	-.25***	-.29***	-.13***	-.17***	.03
Collaboration quality (CQ)	--	.16***	--	.16***	--
Size	-.23***	-.24***	-.16***	-.17***	.02
Age	.38***	.39***	.36***	.37***	.14***
Country	.39***	.42***	.31***	.34***	-.17***
Task relevant expertise	-.03	-.02	-.05	-.04	-.04
Supplier involvement timing	.25***	.23***	.18***	.14***	.16***
Chi-square (df)	2082.77 (797)	2656.10 (795)	2022.41 (797)	2656.10 (795)	2656.10 (795)
RMSEA	.060	.062	.060	.062	.062
NNFI	.95	.93	.95	.93	.93
CFI	.96	.94	.96	.94	.94
IFI	.96	.94	.96	.94	.94
SRMR	.070	.074	.070	.074	.074
R-square	.27	.29	.20	.22	.61

Table 5-6 Regression analysis of CQ's mediation effects

Variables	Design Quality			Design efficiency			CQ
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 4
Intercept	***	***	***	***	***	***	***
Firm age (log)	.23***	.24***	.22***	.20***	.20***	.19***	.07
Firm size (log)	-.01	-.03	-.02	.05	.03	.04	-.05
Firm sales (log)	-.19**	-.17*	-.18**	-.16*	-.13$^{\psi}$	-.14*	.03
Country	.22***	.20***	.20***	.16***	.14**	.15**	.01
Supplier involvement timing	.05	.14**	.13**	.05	.10*	.09	.06
Task relevant expertise	-.01	-.03	-.02	-.02	-.04	-.04	-.01
Communication Intensity		.04	-.00		.07	.03	.21***
Goal congruence		.14**	.02		.18***	.05	.60***
Technical uncertainty		.07	.06		-.03	-.04	.04
Relational uncertainty		-.23***	-.23***		-.12*	-.12*	-.01
Collaboration quality			.19***			.21***	--
Adjusted R-square	.14	.23	.25	.09	.15	.17	.43
R-square change	.15	.10	.02	.11	.06	.02	--
Significance of F statistics	***	***	***	***	***	***	***
Significance of F change	***	***	***	***	***	***	--

$^{\psi}$ p<0.10, *p<0.05, **p<0.01,***p<0.001, n=426

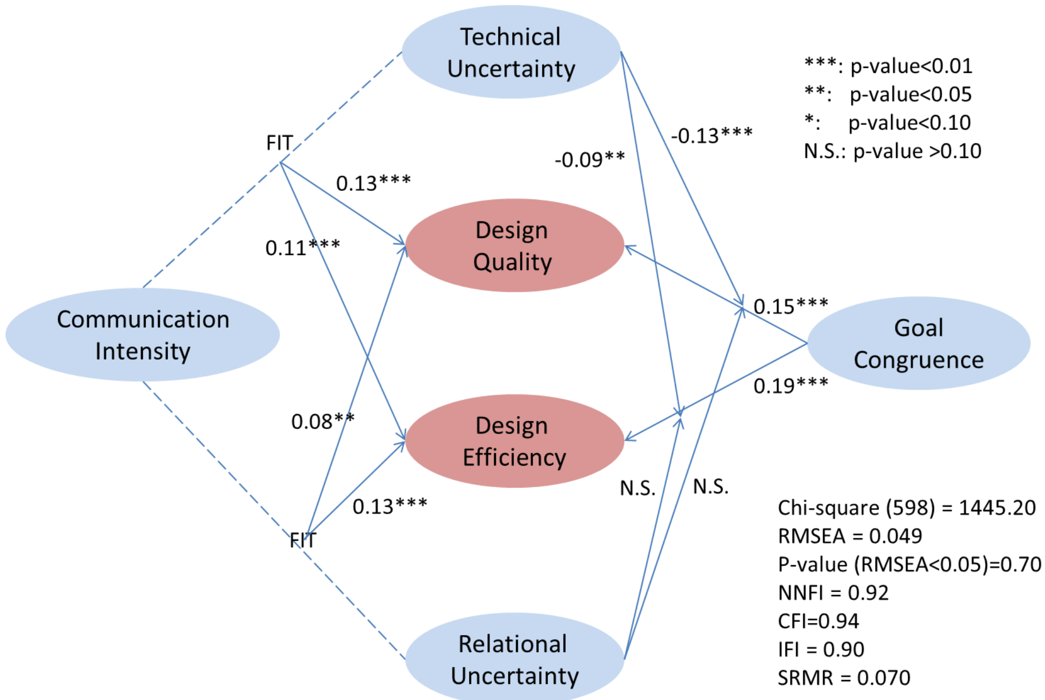
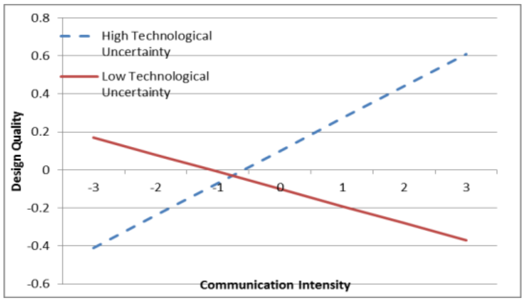
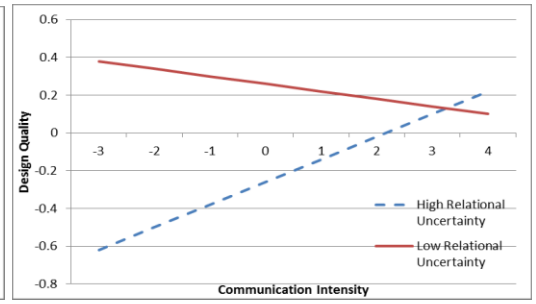


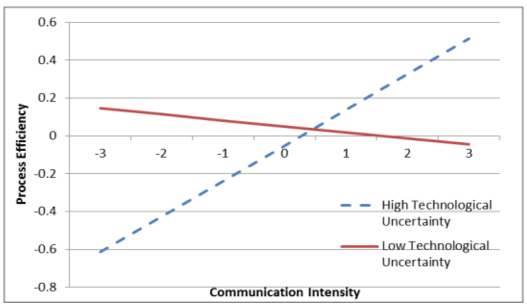
Figure 5-1 SEM analysis result



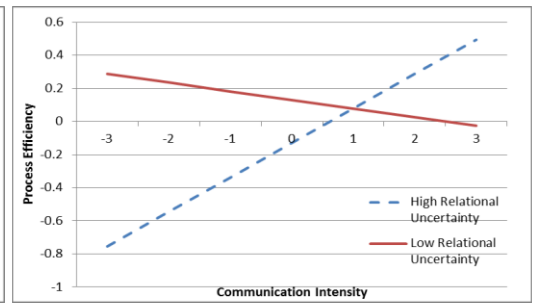
(a)



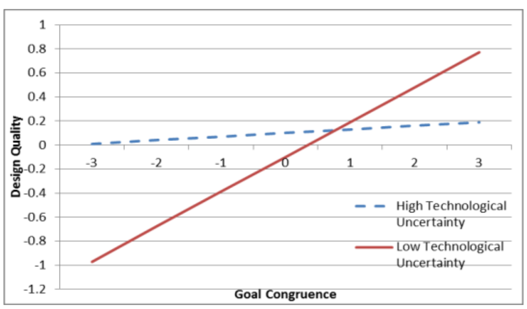
(b)



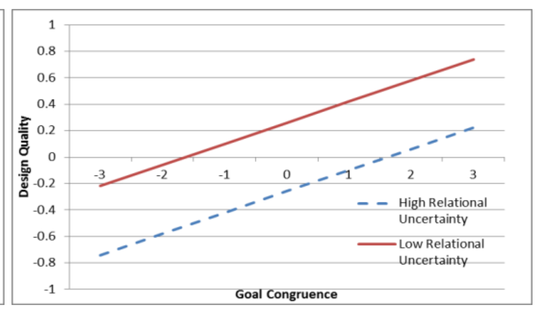
(c)



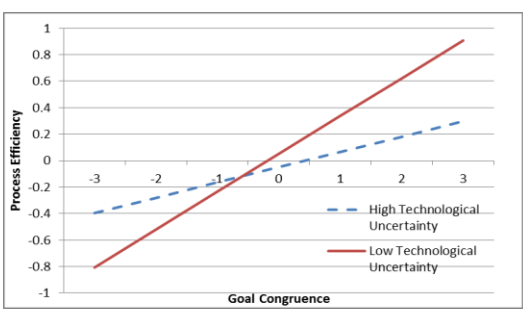
(d)



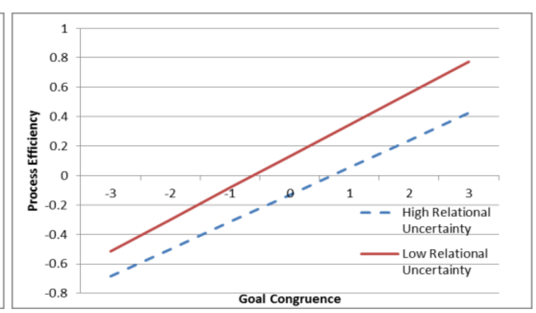
(e)



(f)



(i)



(j)

Figure 5-2 2-Way Interaction Plots

6 CONTRIBUTIONS, LIMITATIONS AND FUTURE RESEARCH

6.1 Summary of results

6.1.1 Summary of hypotheses-testing results

The SEM moderation analysis supports the positive impacts of the fit between communication intensity and both types of uncertainty on buyer-supplier joint innovation project performance. Specifically, if either technical or relational uncertainty is high, intensive communication increases both design quality and design efficiency. On the other hand, a moderate amount of communication between the two firms is best when uncertainty is not lower. Furthermore, communication intensity alone does not have significant main effect on project performance. Thus it is the fit between communication and uncertainty, rather than the level of communication intensity alone, which matters for a successful collaborative innovation project involving a buying firm and a supplier.

Second, the hypotheses concerning the positive effects of goal congruence on project performance are supported. Thus when the two firms perceive they are more likely to simultaneously achieve their respective project and product goals, they are more likely to create a good design in an efficient manner. Incongruent goals lower commitment from both sides and create conflicts among inter-firm interactions, which reduces design quality and design efficiency.

Third, the technical uncertainty of the joint project is found to reduce the positive effects of goal congruence on both design quality and design efficiency. In other words, in a technically complex project (e.g., tasks are not decomposed in a modular way across firm boundaries, products under design are complex, and/or technologies are new), the negative effects of goal incongruence on project performance are reduced. By participating in healthy debates to resolve conflicts in project and product goals, members from the two firms are forced to think more thoroughly trade-offs among different options, thus enabling them to find the optimal solutions for technically challenging problems in a more efficient way.

Fourth, relational uncertainty between members from the two firms is not found to affect the positive effects of goal congruence on project performance. Thus goal congruence is equally important for a successful collaboration, no matter whether the buying firm is working with a supplier that it knows well or with which it collaborates for the first time.

Finally, collaboration quality, a new construct developed in this study, is found to fully mediate the positive effects of goal congruence on joint project performance. In other words, without improving the effectiveness of the collaboration process (e.g., high quality communication, knowledge/skill-based contributions, coordinated activities, etc.), congruent goal structures are unlikely to improve either design quality or design efficiency. Although communication intensity does not have a significant main effect on project performance, it is significantly and positively associated with collaboration quality. Thus, similarly, without improving the quality of the collaboration process, intensive communication between the two firms is not helpful in improving collaboration outcomes.

6.1.2 A comparison of the U. S. and China samples

A comparison of the descriptive statistics of the 13 main constructs used in the moderation and mediation models is shown in Table 6-1. Averaged sums of items for each constructs are used in forming the table. From the table, we can see that 7 out of the 13 constructs differ significantly across the two samples. Specifically, the U.S. sample has higher communication intensity between the buying firm and the supplier, more interdependent task structures across firm boundaries, design more complex products, adopt newer process technologies, share more idiosyncratic investments with suppliers, design higher quality products in a more efficient way.

INSERT TABLE 6-1 HERE.

Although it is established that the same measurement model holds across the U.S. and the China samples, it is not clear whether the same structural model (e.g., the path coefficients from independent constructs to dependent constructs) holds across the two samples. Thus a two-group SEM analysis is conducted to test structural equivalence of the two samples. Specifically, two two-group SEM models, Model 1 and Model 2, are run to test structural equivalence of the moderation as well as the mediation model. Model 1 is the full equivalence model, where all the estimated parameters are constrained to be invariant across the two samples. Nested within Model 1, Model 2 relaxes the equivalence constraints of path coefficients among constructs, thus is called a configural equivalence model. Each model's goodness-of-fit is evaluated by examining Chi-square statistics, RMSEA, NNFI, CFI, and IFI indices. Then a Chi-square difference test is conducted (comparing Model 1 with Model 2) to see whether Model 2 fits the data statistically significantly better than Model 1. If Model 1 fits the data well, then structural equivalence is established, which means the strengths and directions of relationships among constructs are invariant across the two samples. If Model 1 does not fit the data well and Model 2 significantly improve the fit, then we could conclude that two samples only have configural invariance in the structural model.

Table 6-2 shows the results, which shows that Model 1 in both the moderation and mediation analyses do not fit the data well, suggesting that the two samples are not equivalent in path coefficients from independent constructs to dependent constructs. Furthermore, the chi-square difference tests suggest that Model 2 (the configural equivalence model) significantly improve the fit. Lastly, Model 2 fits the data acceptably well. Thus the conclusion is that the samples, although invariant in the measurement model, vary in the strength and/or directions of path coefficients among constructs. However, the two-group SEM analysis does not tell us where the structural variation is. Thus it is possible that the negative impacts of the misfit between communication intensity and uncertainty on project outcomes are greater in one country than those in the other. It is also possible that congruent goals improve collaboration outcomes to different extents across the two countries. Identifying and explaining the structural differences are out of the scope of the current discussion. Deeper analysis should be conducted to examine how manufacturers from different countries vary in their collaborative innovation with suppliers and theoretically explain the differences.

INSERT TABLE 6-2 HERE.

6.1.3 Main effects of uncertainty, timing and expertise

The main effects of technical and relational uncertainty, though not directly hypothesized and tested, should be of interest to NPD managers. From both the SEM moderation analysis as well as the hierarchical regression analysis, technology uncertainty is not significantly associated with project performance, while relational uncertainty is negatively associated with both design quality and design efficiency. A discussion of main effects associated with technical and relational uncertainty, beyond their moderating roles, can be found in section 6.2.3 and 6.2.4. Furthermore, both analyses identify significant positive relationships between supplier involvement timing and project performance. Thus the earlier a manufacturer involves its suppliers into the project, the better the design and the more efficient the process, which is consistent with the literature advocating for early supplier involvement in customers' NPD projects (Clark 1989, Blenkhorn and Noori 1990, Petersen et al. 2005; Wasti and Liker, 1997; Petersen et al., 2003; Ragatz et al. 1997). . Surprisingly, task relevant expertise is consistently found to be not significantly associated with any performance measure. A discussion of this counter-intuitive finding can be found in section 6.2.6.

6.1.4 Individual dimensions of technical and relational uncertainty

In this study, the different sources of uncertainty are aggregated under two constructs: technical and relational uncertainty, to examine their impacts on collaboration outcomes. However, it is also interesting to know how individual sources of uncertainty affect project performance. Thus both SEM and hierarchical regression analyses are conducted to examine this. Table 6-3 shows results from both analyses, which generate very consistent results. Both analyses found that product complexity is not significantly associated with either design quality or design efficiency. Task interdependency is only negatively associated with design efficiency, with no effect on design quality. Surprisingly, product technological newness is significantly associated with better design quality and more efficient processes, while process technological newness significantly reduces design efficiency. In the SEM analysis, process technological newness is also found to reduce design efficiency. According to both analyses, the two reducers of relational uncertainty, coordination efforts and idiosyncratic investments, have consistent effects on project outcomes. Both are positively associated with design quality and efficiency.

INSERT TABLE 6-3 HERE.

6.1.5 Individual dimensions of collaboration quality

Collaboration quality, measured by 16 items in five dimensions, is found to be the mediating process for realizing the benefits of intensive communication and congruent goals. The five dimensions are communication quality, sufficiency of efforts, mutual support, coordination, and knowledge/skill-based contributions However, each individual dimension's mediating role was not examined. Specifically, how do communication intensity and goal congruence affect each dimension and how does each dimension affect project outcome? Hierarchical regression analysis is used to explore answers to these questions.

Table 6-4 shows the correlation between the five collaboration quality dimensions and the two dependent variables. From the table, we could see that all the five dimensions are significantly correlated with both types of project outcomes. Comparatively, the fifth dimension, coordination, has the highest correlations with both design quality and design efficiency.

INSERT TABLE 6-4 HERE.

However, such bivariate correlations do not exclude effects of other variables on the outcome, thus not necessarily reflecting the true relationships among constructs. Thus hierarchical regressions are run to test main effects of each dimension on project performance. Table 6-5 shows the results. Surprisingly, many dimensions of collaboration quality are not significant predictors of project performance. Only coordination is significantly associated with design quality. This may be due to the high positive correlations among the five dimensions of collaboration quality, which cause multi-collinearity in the regression analysis (the VIF scores for all the five collaboration quality dimensions are close to 3).

To cope with the multi-collineearity problem, I run two sets of regressions (one for design quality and one for design efficiency). In each set, five regressions are run, each of which keeps only one collaboration quality dimension by removing the other four dimensions from the model. In this way, main effects of each dimension, without being interfered by other dimensions, on project performance could be identified. The second column for each collaboration quality dimension shows standardized regression coefficients from this set of analyses. Some dimensions of collaboration quality is only significantly associated with one type of performance. For instance, mutual support only contributes to design efficiency but not design quality. Communication quality, just the opposite, improves design quality but not design efficiency. The other three dimensions significantly improve both design quality and design efficiency. Consistent with the correlation analysis, coordination still has the most significant relationships with both types of performance.

INSERT TABLE 6-5 HERE.

Effects of communication intensity and goal congruence on each individual dimension of collaboration quality are examined in another set of regression analyses, each with one collaboration quality dimension as the dependent variable. Table 6-6 shows results from the analyses. Intensive communication and congruent goals contribute to all the five dimensions of collaboration quality. Comparing the standardized regression coefficients, I found that communication intensity contributes most to a higher level of mutual supports, while congruent goals are most important for ensuring a sufficient level of efforts.

INSERT TABLE 6-6 HERE.

6.2 Discussion of results

6.2.1 Communication intensity

Intensive communication is almost always advocated as an important success factor for projects (Lakemond et al., 2006; Takeishi, 2001; Jayaram, 2008; Ragatz et al. 2002; Jayaram 2008). Whenever a task is is decomposed to be completed by multiple units, frequent and intensive inter-unit communication minimizes interferences among decisions made independently by each unit (Sosa et al. 2004). A timely exchange of information among collaborating partners ensures all the perspectives and opinions are considered in making decisions. Intensive communication channeled through rich media, such as face-to-face meetings and audio calls, creates a way through which tacit knowledge could be learned and mild emotions could be felt (Daft and Lengel, 1986; Vickery et al., 2004). Such intimate contacts make sure timely adjustments could be made to accommodate each other’s needs. Furthermore; enough inter-unit communication contributes to building up a harmonious atmosphere by removing misunderstanding and establishing common understanding. Such collaborative atmosphere motivates every member contributes fully to the joint task, thus improving collaboration performance. However, the costs of communication in joint projects in terms of consuming limited project resources, such as time and money, have been largely ignored by the literature (Hoegl and Wagner, 2005). It seems that communication is typically frames as "the more, the better".

One of the main findings in this study, thus, is to point out that too much communication can occur. It is commonly known that "under-communication", the situation when the amount of information exchange among project members does not provide enough information processing capacity to manage the uncertainty in the project, is associated with lower project effectiveness and efficiency. However, communication itself also consumes project resources (Hackman, 1987). Resources, such as rooms, computers, projectors, phones, Internet, travel expenses, etc., which are not free, need to be reserved to enable communication. When more such resources need to be reserved for communication, less time and money could be devoted to value-adding activities that improve the design, given the limited project resource. Thus, when project resources are diverted to support unnecessary communication, both design quality and efficiency suffer. In sum, neither under- nor over-communication helps with improving project performance. There should be an optimal level of communication intensity. When exceeding the optimal level, intensive communication becomes counter-productive.

This finding is consistent with the observation of Joe Spolsky's, CEO of Fog Creek Software, that over-communication has become a common illness of the current management system (Spolsky, Feb. 1st, 2010, http://www.inc.com/magazine/20100201/a-little-less-conversation.html). In its article, Mr. Spolsky wrote:

"*Now, we all know that communication is very important, and that many organizational problems are caused by a failure to communicate. Most people try to solve this problem by increasing the amount of* *communication: cc'ing everybody on an e-mail, having long meetings and inviting the whole staff, and asking for everyone's two cents before implementing a decision.*

But communications costs add up faster than you think, especially on larger teams. What used to work with three people in a garage all talking to one another about everything just doesn't work when your head count reaches 10 or 20 people. Everybody who doesn't need to be in that meeting is killing productivity. Everybody who doesn't need to read that e-mail is distracted by it. At some point, overcommunicating just isn't efficient."

Although some previous studies have found that communication intensity is not always significantly associated with project performance in a positive way, they either fail to explain the insignificant main effect of communication on performance or to identify the optimal level of communication intensity in NPD projects. For instance, Kahn (1996) finds that frequent regulated inter-departmental communication, such as meetings, telephone calls, emails, etc., which are used to address formally coordinated activities, is not a significant predictor of NPD project performance. However, in its post hoc analysis, this study does find that some forms of communication between departments do predict greater project success. For instance, manufacturing mangers' perception of product development success was positively correlated with Fax exchange with R&D. So the author claims that "these (post hoc) findings do indicate that a few elements of interaction correlate with greater performance success… This provides tentative evidence that interaction has a role as a component of integration." (Kahn, 1996, p. 147) However, it does not identify when such communication-based interaction is productive and when it is not.

Similarly, both Hartley et al. (1997a) and Hartley (1997b) do not find support for a positive relationship between buyer-supplier communication and product development outcomes. Even more surprisingly, Hartley et al. (1997a) found a significant negative relationship between frequent buyer-supplier phone calls and suppliers' on-time performance. The authors explained this finding by proposing that "phone calls are a reaction to supplier-related problems encountered during development". The resource-consuming nature of buyer-supplier communication, however, is not discussed in this study. In examining 28 product development projects involving buyer and supplier members, Hoegl and Wagner (2005) found that communication intensity and frequency has an inverted U-shaped relationship with project development budget and product costs. Although this study recognizes the costs of communication, it does not provide guidance on how to determine the "optimal" level of communication between members from the two firms.

Recognizing both the benefit and cost of communication, my dissertation offers guidance on how to determine the "optimal" level of communication across firm boundaries in NPD projects. Compared to previous studies that only recognized the inverted U-shaped relationship between communication and performance, this study offers R&D managers more specific assistance in structuring the communication flows through identifying the "optimal" level of communication intensity. Knowledge that too much communication is counter-productive alone is insufficient for managers to design the best communication channels--they need to know what factors they should consider when determining an appropriate communication channel.

Specifically, this study found that the level of communication intensity should match the level of uncertainty in the project. In other words, the optimal level of communication intensity is the one that is enough to manage all the uncertainty in the project. When communication intensity has not reached this optimal level, its benefits outweigh costs, thus suggesting a positive effect on project outcomes. When communication intensity exceeds the optimal level, it is no longer productive because project resources are used on unnecessary communicating activities. Thus this study clarifies the meanings of "too much" or "too little" communication in joint NPD projects from an information processing, or uncertainty management, perspective.

The fit between communication intensity and both types of uncertainty, technical and relational, are found to improve both project effectiveness (design quality) and efficiency (design efficiency). Technical uncertainty is composed of three dimensions, task interdependence, product complexity and technological newness, while relational uncertainty is caused by a lack of coordination efforts and idiosyncratic investments between the two firms. The former is associated with the technical difficulty of the project, while the latter measures the cooperativeness of the inter-firm relationship. The significant positive association between communication-uncertainty fit and project performance suggests that both types of uncertainty need to be considered when designing the communication channel. For instance, to avoid misunderstanding, the two firms may need frequent communication when they collaborate for the first time (high relational uncertainty), even for designing a very simple product using well-established technology (low technical uncertainty). Similarly, richer communication medias, such as face-to-face meetings, may need to be scheduled to avoid design interferences when project tasks are highly interdependent (high technical uncertainty) between two firms, who may have known each other well for a long time (low relational uncertainty).

A peripheral finding is that communication intensity alone does not have a significant main effect on either design quality or design efficiency. This suggests that merely increasing the amount of information flow between the buyer and supplier firms does not necessarily help with delivering a better product design in a more efficient way. When communication is not conducted to manage either technical or relational uncertainty, it may be a waste of resources and counter-productive to project success. To contribute to project success, communication should be used to coordinate interdependent project tasks, explore the complex interactions among product components, understand features of the new technology, and/or recognize and adapt to routines and assumptions held by members from the partnering firm. Otherwise, the cost of communication may cancel out any benefit associated with the information exchange process.

6.2.2 Goal congruence

My dissertation confirms the positive effects of congruent inter-firm goals on joint NPD project outcomes. Regardless of how technically challenging the project is and/or how cooperative the buyer-supplier relationship is, it is always important for project members from both firms to agree on project and product goals at the beginning of the collaboration. Even if they cannot share exactly the same goals, they at least need to perceive a high probability of simultaneous goal achievement. A lack of goal congruence lowers commitment from both sides and creates conflicts among inter-firm interactions, which reduce design quality and design efficiency. This finding implies the importance of clarifying misunderstandings and establishing a common vision early in the collaboration process for ensuring a successful joint project. Without congruent goals at the beginning, it is less likely to have smoothly coordinated actions and fully committed members during the joint project.

However, the strength of goal congruence's positive effects on project performance is contingent on the level of technical uncertainty. Specifically, for a technically uncertain project, it is less important for members from the two firms to have congruent goals. Holding conflicting project and/or product goals, the two subgroups are forced to resolve the conflict in order to proceed with their respective tasks. For instance, suppose the manufacturer subgroup believes minimizing project cost is the primary goal, while the supplier group insists to use the novelist, and thus expensive, product technology to increase innovativeness. The cost-minimization priority will drive the manufacturer group to fight against using the expensive technology. Thus the two groups have to figure out a way to improve innovativeness without increasing cost substantially before the whole project team could proceed. The conflict resolution process enables a broader consideration of different perspectives and a deeper thinking of trade-offs among different paths, which is quite essential for highly uncertain project where no standard and routine solution exists.

This finding has important implications for selecting suppliers to be involved in manufacturers' NPD projects. When the project is technically challenging (e.g., working on a very complex product, adopting a new product/process technology, and/or high inter-firm task interdependence.), suppliers who are able to bring in ideas that are different, or even conflicting, with the manufacturers', may help generating more innovative solutions in a more efficient way. Such benefits from resolving conflicts, though not necessarily outweigh the friction cost caused by the conflicts, may justify working with suppliers that do not say "yes" to whatever the manufacturer proposes. . An example in case is the collaboration between Renault and Matra, whose collaborative innovation gave birth to the Espace, one of the most innovative and successful car models in Europe in the 1990s. However, at the beginning of their collaboration, the two companies do not agree with each other on a lot of technical issues. Thus project members from the two firms need to resolve conflicting opinions and remove doubts through a lot of debate and discussion, which actually force them to think more deeply, broadly and innovatively. On the contrary, the collaboration between Fiat and Peugeot was quite harmonious. Engineers from each side hailed the excellent atmosphere of camaraderie during the collaboration. However, Ulysse, the minivan developed out of this collaboration, failed to attain even half of its predecessor's success due to a lack of innovativeness.

The proposed role of relational uncertainty in enhancing the importance of goal congruence is not supported. This may be due to the difference between inter-firm level relational uncertainty and project-level inter-group relational uncertainty. For instance, it is not impossible that the two groups of people, one from each firm, have worked on joint projects before, thus knowing each other quite well, though the two firms do not either have a long cooperative experience or invest relationship-specific resources to further improve the relationship. Similarly, it is also possible that the two subgroups work together for the first time, while the two firms have a very good relationship (e.g., working on a lot of joint projects tailed to fit each side's needs or sharing a long-term orientation to strategically develop the relationship). Future studies should be conducted to directly measure relational uncertainty on an inter-group level in order to validate this explanation.

This insignificant moderation effect shows that inter-firm level uncertainty has a smaller impact on the need to align goals among members from the two firms, compared to project-level uncertainty. This makes sense because inter-firm relational uncertainty only represents an "expected" level of behavioral uncertainty between people from the two firms when working together, which may be different from the "actual" relational uncertainty in one specific project. On the contrary, project-level technical uncertainty, influenced by product complexity, technological newness and task interdependence, directly measures the information gap between what is known and what needs to be known to complete the project task. As supported by the data, the larger the technical information gap, the more important for project members to consider a wider variety of perspectives and debate trade-offs among different goals in order to produce the best design with the least project resources consumed.

6.2.3 Technical uncertainty

Beyond moderating the effects from communication and goal structures on project outcome, technical uncertainty alone does not significantly affect performance. This suggests that whether a manufacturer and a supplier could successfully collaborate in product innovation does not depend on the amount of technical challenges within the project. Intuitively, we would think that it is more difficult to produce a good design within project budget and timeline when the project is technically more challenging. Specifically, when tasks are more interdependent between the two firms, products are more complex and technology is newer, the path to the target, a good product developed in an efficient way, is less clear and has to be discovered via iterative trial-and-error. However, the insignificant main effects of technical uncertainty on project outcomes may also suggest that a technically more challenging project offers more opportunity to innovate.

In fact, all the three causes of technical uncertainty could potentially create more opportunities for producing breakthroughs. Complex products have a larger number of components and a greater level of inter-component dependency. On one hand, a more complex product is more difficult to design. On the other hand, however, a complex product also provides more opportunities for improvement. For instance, although it is more technically challenging to develop a car than to design a water bottle, a minor modification in one of thousands of components may significantly improve the car performance. For a simple product, such as water bottle, however, similar improvement opportunities are more likely to have already been well exploited due to its simplicity in design, leaving little room for further breakthroughs. As it is said in an old Chinese saying: the best cook is one who can cook simple dishes well! This is because everybody could cook simple dishes and numerous attempts have been made to improve them, leaving few opportunities for innovation. Complex products, however, may have not been well understood due to the huge number of intricate interactions among components. Thus if resources could be spent on better understanding such products, breakthroughs are not far away. Therefore, it is possible that the benefits and costs of designing a complex product cancel each other out, leading to insignificant main effects from product complexity onto project outcomes (see Table 6-3).

Adopting new product/process technology in NPD projects, though risky, makes radical innovation more likely to occur. Investing in a technology that has not been widely adopted by other companies is a risky decision. This is because features, reliability, costs and performance of the technology have not been well understood, creating difficulties in properly using the technology for developing the new product. In the same time, however, new technology often offers products unique advantages, such as superior quality, user friendliness, lower costs, etc., compared to what existing technology could. Thus if the firm could succeed in utilizing the new technology to develop new products that better meet its customer's needs, gains may be significantly higher due to the first-mover advantage. This is why Daimler AG recently announced plans to set up a manufacturing venture with Japan's Toray Industries Inc. to develop lightweight carbon-fiber auto-body parts, a burgeoning but costly approach to improve fuel efficiency (Fuhrmans, 2011). The venture will begin mass-producing carbon-fiber parts for Mercedes models in 2012. Albeit highly labor intensive to use, carbon fiber is half the weight of steel and 30% lighter than aluminum and can be woven and molded into parts that are stronger than steel. The material is viewed as integral to mass-producing electric cars, in order to counterbalance the extra weight of their batteries and improve range. The high processing and molding costs in using carbon-fiber is preventing most auto manufacturers from using it. So if this Daimler AG-Toray venture could succeed in producing low-cost carbon-fiber parts, it could easily dominate the carbon-fiber auto parts market due to the rarity of competitors. Actually both Daimler AG and Toray have said that they have developed technologies that significantly shorten the molding time, and therefore costs, thus one step closer towards earning the benefits from this new material.

Newer technology's greater potential in producing radical product innovation is supported by the significant positive effect of product technology newness on design quality (see Table 6-3 for results of the ad-hoc analysis). Furthermore, adopting a new product technology in a NPD project even contributes to meet budget and time targets of the project. This is surprising because it is usually believed that when using a newer technology it is more likely to spend longer time and incur higher costs in using the technology properly for developing the product. Actually, process technology newness is found to reduce design efficiency in both the regression and SEM analyses (see Table 6-3 for details). Product technology newness's positive effect on design efficiency may be attributed to new product technology's potential in cost reduction and time saving in the manufacturing stage. A new process technology, however, significantly modifies the way that products are usually manufactured (e.g., adding or removing manufacturing stages, modifying process layout, and/or using new manufacturing technologies). Such modification in the manufacturing process requires more behavioral changes and facility adjustments, which may be very resource-consuming. For instance, only 2% of companies that implementing a lean program, one of the most influential manufacturing processes in the 20th century, achieved their anticipated results, according to a large survey conducted by Industry Week in 2007 (Pay 2008). A major reason for such a low success rate is a failure to change organization members' value orientations and behavioral patterns to fit the way of thinking underlying lean practices (Kull et al., working paper). For instance, there is core belief in lean manufacturing that people are internally motivated to perform well but are restricted by how the system is designed (Rother, 2009). Facilities that implement LM techniques but continue to blame employees for failure will have failed expectations (Liker et al., 2010). Similarly, the successful implementation of a lean program relies on establishing a continuous improvement routine (Nicholas 1998; Womack and Jones 1996; Liker 1998), which is contradicting to human's nature to develop well-worn neural pathways that make it comfortable to do things the same way again and again (Liker and Rother 2011). Thus it may be less risky when adopting a new product technology, compared to a new process technology, for meeting a buyer-supplier joint NPD project' budget and time goals.

Task interdependence, the third source of technical uncertainty, is also a double-edged sword. Although dividing project tasks across the two firms in a modular way is often advocated due to the potential in improving efficiency, a lack of task interdependence prevents learning opportunities between the two firms from being fully exploited. On one hand, when inter-firm task interdependence is low, the two firms could proceed with their respective tasks in a parallel way, thus shortening time in completing the project. Thus task interdependence should be negatively associated with design efficiency, which is confirmed in the ad-hoc analysis (see Table 6-3 for details). Furthermore, a low level of task interdependency may also contribute to creating a better design through diverting project resources from inter-firm coordinating activities to design-improving engineering activities. On the other hand, a lack of inter-firm interactions limits the opportunities for learning. Without intensive inter-firm interactions, such as those through person-to-person direct communication, frequent electronic information transfer and informal socialization when physically collocated, noncodifiable knowledge is hard to be effectively transferred (Allen et al. 1980; Tyre and von Hippel 1993; Carter and Miller, 1989). Task interdependency's negative effect on learning opportunities may counterbalance its positive effect on design quality through devoting more resources to improve the design, leading to an insignificant impact on design quality (see Table 6-3 for details).

6.2.4 Relational uncertainty

Both the regression and SEM analyses find out that relational uncertainty, as a single construct, is negatively associated with both design quality and design efficiency. Thus, in addition to increase the importance of inter-firm communication for ensuring a successful collaboration, high relational uncertainty directly worsens project performance. This implies the importance of selecting a supplier with whom the manufacture has low relational uncertainty, or a cooperative relationship, to be involved in NPD projects. Working with a supplier with which the manufacturer has never worked before implies a long "warm-up" period for people from both sides to know and trust each other. Members from two partners with a long collaboration experience, however, could immediately start working on project tasks. A cooperative buyer-supplier relationship also suggests that the buyer and supplier firms mutually invest in relationship-specific resources, which indicates a shared long-term orientation in strategically building up the relationship to meet each side's needs (Jap 1999). Such inter-firm level strategic congruence contributes to build inter-group level trust between project members from the two firms. When people who work together trust each other, they constructively discuss issues, openly share ideas, trust each other, adapt to each other's changing needs, and consider each other's interests when problem arises. Such a collaborative atmosphere is essential for ensuring high decision quality and design efficiency in collaborative projects.

Both indicators of a cooperative buyer-supplier relationship, coordination efforts and idiosyncratic investments, are positively associated with design quality. This finding suggests that repeated collaborations between firms do help improve the effectiveness of future collaborations, or the quality of the product design in this study. Specifically, when a manufacturer is considering which supplier to collaborate in a NPD project, given everything else the same, those with which it has longer collaboration experience should be given priority. Furthermore, relationship-specific investments between the two firms also help improve the effectiveness of inter-firm interactions by cultivating an atmosphere of camaraderie, on one hand, and preventing opportunistic behaviors from happening, on the other hand. Thus working with suppliers who want to extend their relationships with the buyer into the future in a mutually beneficial way helps improve the quality of the new product design.

However, neither coordination efforts nor idiosyncratic investments significantly contribute to a more efficient collaboration process. Thus working with a supplier firm which the manufacturer knows well does not necessarily mean the joint project is more likely to meet either cost or time targets. Whether the collaboration process is efficient or not may depend more on technical challenges (such as inter-firm task interdependence, process technological newness, etc.) and/or the inter-firm goal structure (e.g., goal congruence) in the project.

An example in point is Boeing's 787 Dreamliner, which is a long-range, mid-size, wide-body, twin-engine jet airliner with a capacity of 210 to 330 passengers. The development and production activities of 787 have involved a large-scale collaboration with numerous suppliers around the globe. Most of these suppliers have worked with Boeing for a long time across a lot of joint projects and have long-term orientation in building their relationships with Boeing into the future. For instance, before being involved in developing 787, three Japanese suppliers, Mitsubishi Heavy Industries, Kawasaki Heavy Industries and Fuji Heavy Industries have already successfully collaborated with Boeing in developing 767 and 777 (Gordon 1997). After developing engines for 787, Rolls-Royce and Boeing extended their relationship through a collaborative research agreement to explore the potential of fuel-efficient open-fan (open rotor) propulsion technology for future commercial airplanes in 2009 (Boeing Media, 2009, http://www.boeing.com/news/releases/2009/q2/090507a_nr.html). However, such cooperative relationships with suppliers do not help Boeing from preventing a series of delays of in delivering its Dreamliner 787. A lack of control of the complex supply chains, which are largely determined by the Dreamliner's complex product architecture, is believed to be the main cause of the delays. Specifically, several commonly-believed causes of the delays, such as the ongoing fastener shortage, the lack of documentation from overseas suppliers, continuing delays with the flight guidance software, and the incorrect fastener installation due to unclear installation specifications, all indicate the challenges in managing such a technically challenging NPD project as 787 (Carpenter 2007; Clark 2007; Boeing Media, 2007, http://www.boeing.com/news/releases/2007/q4/071010d_nr.html; Gates, 2008).

6.2.5 Collaboration quality

Collaboration quality's role in fully mediating effects of communication intensity and goal congruence onto project outcomes has several implications. First, identifying collaboration quality as the mediating process helps us understand *when* intensive communication and congruent goals could improve collaboration performance. Specifically, without improving communication timeliness and accuracy, balancing contributions according to knowledge and skills, avoiding interferences among distributed and interdependent activities, maintaining a fully committed project team, and building a collaborative working atmosphere, no matter how much the two firms communicate and how congruent their goals are, it is hard to produce a good design in an efficient way.

Second, the full mediation role played by collaboration quality suggests the importance of monitoring the five dimensions of collaboration quality during the project. Selecting a supplier with congruent goals and/or regularizing intensive inter-firm communication can not ensure a successful collaboration unless all the five dimensions of collaboration quality are improved. Early feedback should be given to project members when symptoms of low effectiveness in inter-firm interactions, such as a lack of mutual supports, one side always dominating the other in decision making, inaccuracy in communication, a lack of commitment, etc, are detected. Such real-time monitoring and immediate adjustments could ensure the realization of the full benefits of inter-firm communication and congruent inter-firm goal structures.

Third, the benefits of intensive communication and congruent goals in improving collaborative innovation outcomes are confirmed by their positive effects on collaboration quality. So the more the two firms communicate during the project and the more congruent goals they have, the more effective they interact during the project. Thus when members from the two firms communicate more frequently and intensively, the communication is more likely to be timely. Without communication, there is no way for one group to know the other group's needs and thus to support and adapt to them. Involving both firms in the decision making process to balance their efforts is impossible if people from both sides do not talk to each other. Similarly, partners sharing congruent goals are more likely to be fully committed to the project, openly share ideas, and go out of its way to help each other out when problem arises, because pursuing one side's goals does not reduce the possibility of the other side to achieve its goals.

When examining individual dimensions of collaboration quality in the ad-hoc analysis, it is found that each dimension affects project outcomes in different ways (see Table 6-4 for details). Coordination turns out to be the dimension that has the greatest positive effects on both design quality and design efficiency if we compare the standardized regression coefficients of each dimension in Table 6-4. The next two most important dimensions are knowledge/skill-based contribution and sufficiency of efforts, in decreasing order, both of which are also significantly associated with both design quality and design efficiency. Communication quality only improves design quality, while mutual supports contribute to a more efficient process. These findings show that when monitoring the collaboration process, managers may need to focus more on coordination of distributed activities and balance of contributions. Specifically, efforts should be devoted to planning and timing activities of members from the two firms to avoid interferences, involving all of those with the right knowledge/skills in the decision making process, and motivating everyone to be fully committed to the project.

6.2.6 Task relevant expertise

Intuitively, project members' task relevant expertise should be an important success factor for NPD projects. According to Hackman's workgroup effectiveness theory, sufficiency of knowledge and skills applied to the group task is an important criterion of group process effectiveness, which contributes to better group performance (Hackman

1987). Because individuals' task relevant expertise is the major source of knowledge and skills that could be applied to project tasks, it should contribute to project success in a significant way. That is why it is important to accurately recognize and effectively utilize such expertise in work groups to improve group performance (Bunderson 2003).

Surprisingly, task relevant expertise of project members is not significantly associated with either design quality or design efficiency. One possible reason may be that project members with more task relevant expertise will have higher performance expectation. Such higher expectation result from a perceived higher probability in achieving project goals. However, when you expect more, it is less likely to feel satisfied. For instance, the American Customer Satisfaction Index model shows that there is a negative association between customer expectation and customer satisfaction (Fornell 1996). So such negative biases related with respondents' performance expectation may counter-balance the positive effects of task relevant expertise on project outcomes, leading to the insignificant effects.

6.3 Theoretical and practical contributions

Theoretically, this study first contributes to the literature by introducing the concept that there is an optimal amount of communication intensity. Literature studying supplier involvement in NPD often focuses only on benefits associated with inter-firm communication. More inter-firm communication seems to be always advocated (Takeishi 2001, Jayaram 2008, Ragatz et al. 2002). Some major benefits identified by the literature include higher design manufacturability (Swink 1999), better design quality (Jayaram 2008, Ragatz et al. 2002, Takleishi 2001), higher design efficiency (Ragatz et al. 2002, Sobrero and Roberts 2002, Jayaram 2008). The costs of communication, however, are largely ignored by the literature. Although insignificant or even negative effects of inter-firm communication on NPD project performances have been identified (Hartley et al. 1997, Hoegl and Wagner 2005), causes of ineffective communication have not received enough attention. This study, adopting a information processing theory's perspective, proposes that communication is not always productive. Inter-firm communication only contributes to project outcomes when there is a lack of information processing capacity to manage the uncertainty, either technical or relational, in the collaboration. Thus, when there is no need for additional information processing capacity, intensive communication is a waste of limited project resources, such as time and money, on non-value-adding activities.

Second, this study theoretically defines and empirically operationalizes two types of uncertainty, one on the project level and one on the inter-firm level, which moderate the effects of inter-firm communication and goal structures on collaboration outcomes. Specifically, three sources of project-level sources of technical uncertainty, product complexity, technological newness and task interdependence, were proposed to affect the level of technical challenges in the project. Two reducers of inter-firm relational uncertainty, coordination efforts and idiosyncratic investments, were proposed to reduce the information gap in predicting behaviors of people from the partnering firm. Differentiating technical uncertainty from relational uncertainty enables researchers to examine their different impacts on project outcomes as well as various roles in affecting other factors' effectiveness in improving performance.

Third, adopting a contingency theory's perspective, this study examines the conditions when goal congruence is more effective in improving collaboration outcomes. Building upon the conflict management literature, the benefits of incongruent goal structures, often ignored by the inter-firm collaboration and NPD literature, are proposed and empirically validated. Specifically, this study found out the potential benefits of conflicting goals, in terms of improving decision quality and design efficiency, in technically uncertain project. Instead of proposing a uniform positive effect from inter-partner goal congruence to collaboration outcomes, this represents a first step in examining not only the benefits but also the costs of congruent goals in inter-firm collaborative innovation.

Fourth, this study nominally and operationally defines collaboration quality, a theoretical construct which measure the *effectiveness* of inter-partner interactions rather than *mere existence* or *amount* of certain activities pursued by partners. It focuses on quality of the process instead of on capability of the collaborating parities (collaboration/alliance capability) (Lambe et al. 2002, Kale et al. 2002, and Duysters 2003, Sivadas and Dwyer 2000, Niemelä 2003). This research contributes to clarifying how collaboration relates to different measures of project success. Thus the construct offers a way to assess the quality of a collaboration process and to actively influence this critical success factor by focusing management activities on improving the five facets of collaboration quality.

Finally, this study proposes several enhancements to existing construct measures. New scales are created for product complexity, task interdependence and collaboration quality. Some modifications to existing scales are proposed for design quality, design efficiency, and goal congruence to better fit the buyer-supplier product design context.

Practically, this study suggests that it is not appropriate to communicate with all the involved suppliers in the same way. Depending on how design task is decomposed between the two firms, how complex the product under design is, and how new the product/process technology adopted to develop the new product, different buyer-supplier dyads may have different levels of technical uncertainty to manage. Similarly, to different extents, project members may lack enough understanding of each other's behavioral routines and assumptions due to a lack of cooperative relationship on the inter-firm level. Such variations in relational uncertainty also affect the effectiveness of different communication structures. In general, higher uncertainty, no matter technical or relational, should be managed through communication channels that enable more frequent and intensive information flows between members from the two firms.

Then, buyers are reminded of costs associated with over-communication. Instead of trying to communicate with suppliers as intensively as possible, buyers should communicate with suppliers at the *right* frequency through the *right* media to avoid either uncoordinated activities or coordinating activities inefficiently. Thus it is possible that the more a buyer communicates with a supplier, the less supportive the supplier becomes due to the overwhelming inaccurate, unnecessary, and/or redundant information provided by the other side as well as the huge amount of efforts spent in providing non-value-adding information to the partner. From the mediation model's perspective, unless the communication improves the quality of the collaboration process, there is no way that intensive communication could improve either design quality or design efficiency. So both the moderating and mediating model explain, from different perspectives, why intensive communication sometimes fails to improve collaboration outcomes.

This study identifies three sources of technical uncertainty, thus offering a more complete view on technical challenges in inter-firm joint product innovation. Recognizing all the three sources could help buyers to correctly estimate the level of technical uncertainty, thus purposefully optimize the inter-firm information flow and maintaining an appropriate goal structures to ensure success. For instance, if technical uncertainty is conceived to be high (e.g., developing a complex product using new product/process technology with high inter-firm task interdependence), then more intensive communication should be advocated, while a certain level of incongruence on project and/or product goals could be allowed to improve the decision making process through conflict-resolving debates.

Relational uncertainty's significant role in increasing the importance of communication intensity as well as its direct negative impacts on collaboration outcomes provide evidence of project-level benefits of a cooperative buyer-supplier relationship. Characteristics of inter-organizational relationships are widely believed to affect how people from the two firms work together (Heide and Miner 1992, Sobrero and Schrader 1998, Heimeriks and Duysters 2003, Manil et al. 2007). For instance, a good buyer-supplier relationship, indicated by rich cooperative experiences, may help cultivating a more productive environment for people from the two firms to work together. However it is also possible that, no matter how good a relationship is on the firm level, operational and relational factors on the project level dominantly determine whether a high quality process emerges. Thus it is important to test links between firm-level relational factors and project-level operational performances, after controlling for project-level factors' effects. It is found in this study that, when buyers involve suppliers whom they have a long cooperation experience with, they could rely less on explicit inter-firm coordination. Thus more project resources could be spent on the core design work. The shared cognition and value held by members from the two firms enable them to coordinate interdependent activities in an implicit way, which significantly increase design efficiency (Espinosa et al. 2002, Espinosa and Pickering 2006). Similarly, the strategic congruence between two firms sharing a cooperative relationship prevents opportunistic behaviors and increase inter-group trust, both of which contribute to a higher quality collaboration process. In addition to increasing the need for explicit coordination, a lack of cooperative buyer-supplier relationship directly reduces design quality and design efficiency.

Empirical validation of goal congruence's positive effects on process effectiveness, and further onto collaboration performance, supports the importance of inter-firm agreements on project and product targets (Petersen et al. 2003). If the two firms do not agree on key targets, friction costs generated by goal conflicts may outweigh benefits of diversity, thus worsening project performance. Therefore, aligning goals, i.e. either through contractual coordination (Sobrero and Schrader 1998) or shared education and training (Ragatz et al. 1997), is critical for a successful buyer-supplier collaboration project. Furthermore, people from the two firms do not need to share exactly the same goals. As long as common goal achievement is possible, performance of the collective output, the product design, will not be compromised.

The negative interaction between goal congruence and technical uncertainty suggests that less emphasis should be placed on goal congruence when selecting suppliers to be involved in manufacturer's NPD projects. This is contradictory to the general belief that only suppliers that shared similar goals with the manufacturer should be involved. When the project is technically challenging, meaning no routine solutions exist and nobody knows what the optimal path is, a certain level of conflicts in goals force project members to think more deeply and openly about the trade-offs among solutions through the conflict resolution process. Such "healthy debates and criticism", however, do not exist if the supplier says "yes" to whatever the manufacturer proposes. Thus among multiple supplier selection criteria, such as supplier technical competence, buyer-supplier relationship, etc, goal congruence could be of less a concern when technical uncertainty of the project is high. However, I am not suggesting that goal congruence is not important when technical uncertainty is high. As shown, goal congruence is always associated with better design quality and design efficiency, no matter whether technical uncertainty is high or low. So efforts should still be spent in aligning project and product goals held by people from the two firms.

Finally this study shows the importance of monitoring the on-going collaboration process. Even if the two firms communicate at the optimum level and have congruent goals, project performance could still be low due to the emergence of a low quality process. Some indicators are that the two firms do not communicate accurate information timely, or that people from the two firms do not support each other's immediate needs, or that they do not apply enough efforts to the core design task due to their respective involvement in other projects. Monitoring the daily inter-firm interaction may prevent a low quality process from emerging by adapting to early signs of low collaboration quality.

6.4 Limitations

The primary limitations of the study are related to the subjective and retrospective nature of the collected data. Poole et al. (2000) argued that the need for inference by the researcher, inaccuracy of perception-based measures, biases associated with recall and the inherent weakness of surveys in causal inference are major limitations of using perception-based surveys. In defense of using perception-based survey, studies have shown that results from perceptual data are comparable to actual data, with satisfactory reliability and validity of findings (Dess and Robinson, 1984; Ketokivi and Schroeder, 2004). The causal inference that design performance is resultant of good coordination and high collaboration quality can be weakened by the retrospective nature of the data collection method. For example, a respondent may perceive the inter-firm interacting process to be more collaborative if the design turns out to be very successful. In this study, I attempts to control for such reverse causal effects by separately collecting information on independent and dependent variables from two independent sets of respondents. However, a process research design which collects longitudinal data along with the progress of the detailed design phase is stronger in establishing the causal chain.

Only buyers' responses are collected regarding project performance as well as inter-firm interactions, which may be biased without being confirmed by supplier's responses. Using buyers' responses as the sole source relies on the assumption that buyers have greater initiatives and assume major responsibility in coordinating the inter-firm joint innovation process. However, suppliers may have different views on how they coordinate with the buyer and how well the collaboration goes. Collecting information from both the buyer and supplier firms, though more resource-consuming, is preferable to enhance the validity and reliability in measuring latent constructs.

External validity of results from this study may be weakened by the small sample size. The two-respondent-per-survey design controls for the bias associated with a single respondent. The cost of using such a design, however, is only a small sample could be surveyed due to the unwillingness of the first respondent to name a second respondent as well as the second respondent's ignorance of the request to fill the survey. Efforts, such as promising the anonymous status of respondents, using multiple contact methods to follow-up with the second respondents, collecting data from both the United States and China, etc, have been spent to maximize the sample size.

6.5 Future research opportunities

Effects of national culture on effective and efficient manufacturer-supplier joint innovation could be examined in future studies using the data collected for the dissertation. As shown in Table 6-2, the two samples, one from the United States and one from China, differ in the strength and/or directions of path coefficients from independent to dependent constructs in both the moderation and mediation models. Such differences imply that the roles of communication intensity and goal congruence affect collaboration quality and project outcomes in different ways. Furthermore, the impacts of technical and relational uncertainty on collaboration outcomes may also be different across the two samples. For instance, relational uncertainty may have a greater impact on project performance in a collectivist culture which values collective work and informal social relationships, such as China, compared to an individualistic culture which values independence and formal rules and instructions, such as the United States.

Impacts of different types of inter-organizational goal congruence on project performances could be further studied. Goals could be different due to different preferences in ranking multiple goals (Type 1). Autonomous units often prioritize goals differently, due to their local expertise and social embeddedness in institutional infrastructure of their respective "communities". However, goals could also be different due to autonomous units' self-serving orientation (Type 2) (Eisenhardt 1989). The classical agency problem is an example of different goals held by cooperating parties. One party (the principal) delegates work to another (an agent), who performs that work. The agency problem occurs when (a) the goals of the principal and the agent conflict due to their respective self-serving orientation, and (b) it is difficult for the principal to verify what the agent is actually doing (Jensen and Meckling 1976, Ross 1973). Such goal conflict could be identified in a lot of relationships, such as employer-employee, lawyer-client, buyer-supplier and so on (Harris and Raviv 1978). Agency theorists have focused on how to limit the agent's self-serving behaviors through contract design for a long time (Jensen and Meckling 1976, Fama 1980, Fama and Jensen 1983). This study subsumes both types of goal congruence under one construct. In reality, however, the two types may interact with each other and affect project outcomes in different ways. For instance, the benefits of goal conflicts in improving decision quality may be only associated with Type 1, while Type 2 may always harm collaboration performance. Field or lab-based experiments could be used to help accurately differentiate and measure both types of goal incongruence. Results of such studies have implications on (1) what the optimal level of Type 1 goal incongruence is, (2) how to contractually coordinate the two parties to *minimizes* Type 2 goal incongruence, (3) how the two types interact with each other in affecting project outcomes.

In this study, I only examine performance of the productive output, a design, of the BG-SG group. According to Hackman's model, however, another important criterion for group effectiveness is enhanced capability of group members to work together in the future. Cooperative competency on an inter-organizational level has been shown to be important predictors of firm performance (Dyer and Singh 1998, Sivadas and Dwyer 2000, Blomqvist and Levy 2006, Heimeriks and Duysters 2007). Thus it is important to examine whether an effective collaborative process in one project could benefit the two firms, in terms of improving cooperative competency, in the future. However, longitudinal data is needed to do such researches.

The three sources of technical uncertainty deserve more future attention. In this study, I identified three sources of technical uncertainty: product complexity, technological newness and task interdependence. However, all the three types are aggregated into one single construct. Such aggregation prevents us from knowing their respective impacts on the need to communicate and to align goals between members from the two firms. It is also impossible to know their individual direct effects on project outcomes. Table 6-3 shows some preliminary results from examining their individual effects. We could notice that the three factors do not affect project outcomes in the same way. For instance, working on a complex product seems not to be associated either with a worse design or a less efficient process, which is contradictory to the common belief. Similarly, product and process technological newness seem to have completely different impacts on project outcomes, with the former one contributing to while the latter one harming both types of project performance. Thus future studies should be conducted to explain such differences.

In addition to the intensity of communication, the media used to facilitate inter-firm communication could affect its effectiveness in coordinating interdependent tasks. For instance, Antioco et al. (2008) found that what communication media is used affects how information is used by product designers, which ultimately influences design performance. Rich communication media, such as face-to-face meeting and phone calls, is more helpful in transmitting tacit knowledge, thus maybe more important for solving problems that are not well defined and thus no routine solutions exist (a high technical uncertainty situation). Less rich media, such as emails and EDI, are efficient in exchanging a large amount of explicit information, thus maybe more applicable to well-defined problems (a low technical uncertainty situation). Similarly, rich communication media may be necessary to establish common understanding when people from the two firms do not know each other well, or when relational uncertainty is high. So it is possible that not only communication intensity, but also communication media richness should fit with the levels of technical/relational uncertainty in order to maximize the project performance.

The other important dimension defining inter-firm coordination, the inter-firm decision making structure, is not examined in this dissertation. When two firms collaborate on joint projects, they not only communicate with each other but also make decisions together. Malone (1987) points out that there are two attributes associated with different coordination mechanisms: information structure (how members share, perceive and communicate information) and decision function (how members decide what actions to take). Three dimensions define the information processing capacity of different decision making structures: formalization (ranging from informal personal meetings to more formal arrangements), cooperativeness (extent of shared decision making), and centralization (locus of decisional autonomy) (McCann and Galbraith 1981). The less formal, more cooperative and less central the joint decision making structure is, the higher the information processing capacity it has, thus more helpful in highly uncertain environment. Future studies should be conducted to examine how to optimize the decision making structure to ensure collaboration success.

Finally, effects of communication intensity and goal congruence on product innovativeness could be further studied. In this study, I only focus on design quality and design efficiency without considering how innovative the product and the process are. Given the importance of creativity as a criterion for evaluating NPD projects, future studies should be done to see whether the proposed model holds when design innovativeness is outcomes that are evaluated.

Table 6-1 Comparative descriptive statistics of the U. S. and China samples

Constructs	U.S. Mean	U.S. S.D.	China Mean	China S.D.	P-value of the T-test
Communication Intensity	3.98	0.85	3.65	1.00	Significant <.001
Goal Congruence	3.96	0.88	3.91	0.87	Non-significant .49
Task Interdependence	3.91	0.84	3.61	0.93	Significant <.001
Product Complexity	2.99	0.99	3.20	1.06	Significant .04
Product Technological Uncertainty	3.24	0.95	3.22	0.86	Non-significant .84
Process Technological Uncertainty	2.66	1.03	2.93	0.92	Significant .01
Coordination Efforts	3.62	1.04	3.60	1.03	Non-significant .84
Idiosyncratic Investments	3.24	1.11	3.01	1.12	Significant .04
Supplier Involvement Timing	2.28	0.72	2.25	0.72	Non-significant .68
Task Relevant Expertise	3.96	0.85	4.01	0.87	Non-significant .52
Collaboration Quality	3.69	0.67	3.64	0.72	.Non-significant .47
Design Quality	14.45	5.13	11.20	5.07	Significant <.001
Design efficiency	12.66	5.63	10.06	5.11	Significant <.001

Table 6-2 Structural equivalence tests of the U. S. and China samples

	Moderation Model		Mediation Model	
	Model 1	Model 2	Model 1	Model 2
Chi-square (df)	2463.76 (1352)	2319.66 (1328)	3085.20 (1656)	2686 (1630)
RMSEA	0.059	0.055	0.071	0.051
NNFI	0.91	0.91	0.95	0.96
CFI	0.92	0.92	0.95	0.97
IFI	0.92	0.93	0.95	0.97
Chi-square Difference Test P-value	p-value <.001 144.10 (24)		p-value <.001 399.2 (26)	

Table 6-3 Effects of individual sources of uncertainty

Independent variables	Hierarchical regression results		SEM results	
	Dependent variable		Dependent variable	
	Design quality	Design efficiency	Design quality	Design efficiency
Age	.261***	.238***	.62***	.54***
Size	-.036	.009	-.26***	-.18***
Sale	-.168**	-.135		
Country	.188***	.131**	.44***	.35***
Time	.147***	.120**	.27***	.24***
Task Relevant Expertise	-.020	-.032	-.001	-.040
Communication Intensity	.036	.077	-.011	.048
Goal Congruence	.124**	.155***	.12**	.16***
Task Interdependence	-.028	-.146**	-.042	-.16***
Product Complexity	.000	-.030	-.022	-.048
Product Technological Newness	.188***	.235***	.28***	.31***
Process Technological Newness	-.065	-.161**	-.10**	-.20***
Coordination Efforts	.155**	.068	.15***	.067
Idiosyncratic investments	.120*	.074	.094**	.062
Adjusted R-square	24.6%	20.3%	30.0%	26%

Table 6-4 Correlations between individual dimensions of CQ and project performance

		CQ_1	CQ_2	CQ_3	CQ_4	CQ_5	PD	PS
CQ_1	Pearson Correlation	1						
CQ_2	Pearson Correlation	.680**	1					
CQ_3	Pearson Correlation	.705**	.676**	1				
CQ_4	Pearson Correlation	.586**	.616**	.665**	1			
CQ_5	Pearson Correlation	.683**	.731**	.701**	.685**	1		
PD	Pearson Correlation	.234**	.190**	.235**	.233**	.263**	1	
PS	Pearson Correlation	.253**	.194**	.245**	.255**	.263**	.668**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 6-5 Effects of individual CQ dimensions on project performance

Independent varaibles	Dependent variables			
	Design quality		Design efficiency	
Size	-.01		.038	
Sales	-.182**		-.135	
Age	.223***		.181***	
Country	.21***		.146**	
Time	.124**		.093	
Task relevant expertise	-.021		-.038	
Communication intensity	.006		.037	
Goal congruence	.024		.056	
Technological uncertainty	.059		-.038	
Relational uncertainty	-.231***		-.124*	
Collaboration quality (CQ)_mutual supports	-.027	.10	.014	.12*
CQ_communication quality	-.018	.111*	-.050	.10
CQ_sufficiency of efforts	.007	.12*	.029	.146*
CQ_knowledge/skill-based contribution	.066	.148**	.097	.170***
CQ_coordination	.186*	.202***	.141	.192***
Adjusted R-square	24.9%		16.6%	

Table 6-6 Effects of communication and goal structures on individual CQ dimensions

	Mutual supports	Communication quality	Sufficiency of efforts	Knowledge/skill-based contribution	Coordination
Country	.042	-.068	-.018	-.012	-.055
Sale	-.012	.096	-.029	-.020	.062
Size	-.019	-.075	-.001	-.007	-.086
Age	.137**	.003	.003	.079	.054
Time	.039	.094*	.026	.028	.057
Task Relevant Expertise	.006	-.033	-.005	-.033	-.003
Communication Intensity	.229***	.220***	.159***	.139**	.175***
Goal congruence	.439***	.515***	.561***	.485***	.536***
Technological uncertainty	.016	.008	.049	.079	.009
Relational uncertainty	.029	-.034	-.082	.070	-.032
Adjusted R-square	28.6%	34%	39%	26.5%	34.2%

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APPENDIX A

SURVEY INSTRUMENTS

Section 1

W. P. CAREY SCHOOL of BUSINESS

ARIZONA STATE UNIVERSITY

Coordination in buyer-supplier product design-Part 1

Many manufacturers are outsourcing design activities to suppliers, and suppliers are playing an increasingly important role in providing product and process innovations. The main purpose of this study is to investigate how design teams of buyers and suppliers interact and coordinate in new product development. We hypothesize that different modes of inter-firm alignment will work better or worse, depending on characteristics of the project. Knowledge from this study will help project managers plan how best to coordinate design teams that involve collaboration between two organizations.

This survey is being conducted by researchers at the W. P. Carey School of Business, Arizona State University. The questionnaire seeks information on design performance of a product, whose development involves a single supplier in the majority of value-adding activities. It also inquires information on supplier involvement strategy and product characteristics.

At your request, a copy of the research findings will be sent to you, allowing you to benchmark your product development practices with those of other companies. Simply indicate your interest at the end of the survey.
All of your answers will be kept strictly confidential. No individual or company will be identified. Only summary data and aggregate results from multiple firms will be published. You have the right to skip any question you choose not to answer. However, we ask that you answer all questions to the best of your ability, as incomplete surveys can create serious problems with regard to data analysis. If you are not sure of an answer to a question, please provide your best estimate.
This questionnaire can be completed in about 5 to 10 minutes.
Participation in this study is completely voluntary.

We will be happy to answer any questions or concerns you may have. Please contact:

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This is the first part of the questionnaire. The second part will be filled in by a project member that you will name below.

In answering the questions below:
-Please consider a recent instance where an external supplier collaborated with your business unit around the design of a new product.
-All of your responses should refer to the collaboration around this specific product.

As mentioned above, the questionnaire has two parts that need to be completed by two different people. Please name another individual from your company who actively participated and interacted with the supplier during the project. Part two of the survey will be emailed to this person.
The other participant will not see your responses
We would greatly appreciate it if besides providing the contact information below you would also contact this person and tell them that you would like them to fill out part two of the questionnaire
Name: ________________________________
Email Address: _________________________

In order for the other participant to refer to the same project you are referring to in this first part of the survey, please provide the following (the information you provide below will not be identifiable in any published results generated from this study):

Project name: _____________________________
Product name: ___________________________
Supplier name: ____
In which year the project started: ______________

Section 2:

1. Product design performance

The product design

was of high quality	1 - 2 - 3 - 4 - 5 Disagree Agree
fully complied with the specifications regarding dimensional integrity	1 - 2 - 3 - 4 - 5 Disagree Agree
fully complied with the specifications regarding durability	1 - 2 - 3 - 4 - 5 Disagree Agree
fully complied with the specifications regarding functionality	1 - 2 - 3 - 4 - 5 Disagree Agree
fully complied with the specifications regarding manufacturability	1 - 2 - 3 - 4 - 5 Disagree Agree
fit the target customers' needs.	1 - 2 - 3 - 4 - 5 Disagree Agree

Please evaluate *the design process* for this product.

Our budget goal for the project was fully achieved	1 - 2 - 3 - 4 - 5 Disagree Agree
The development cost for this product was kept low	1 - 2 - 3 - 4 - 5 Disagree Agree
The development cycle time goal for this product was fully achieved	1 - 2 - 3 - 4 - 5 Disagree Agree
The product design was completed on time	1 - 2 - 3 - 4 - 5 Disagree Agree

Please assess *the aggressiveness of project goals* for designing this product

The development budget goal for this product was very aggressive	1 - 2 - 3 - 4 - 5 Disagree Agree
The development cycle time goal for this product was very aggressive	1 - 2 - 3 - 4 - 5 Disagree Agree
The design quality goal for this product was very aggressive	1 - 2 - 3 - 4 - 5 Disagree Agree
The dimensional integrity goal for this product was very aggressive	1 - 2 - 3 - 4 - 5 Disagree Agree
The durability goal for this product was very aggressive	1 - 2 - 3 - 4 - 5 Disagree Agree
The functionality goal for this product was very aggressive	1 - 2 - 3 - 4 - 5 Disagree Agree
The manufacturability goal for this product was very aggressive	1 - 2 - 3 - 4 - 5 Disagree Agree
The target customers' needs are very difficulty to satisfy	1 - 2 - 3 - 4 - 5 Disagree Agree

Please assess *contributions of the supplier* to this project

Working with this supplier increased our product's technical success	1 - 2 - 3 - 4 - 5 Disagree Agree
The supplier's suggestions improved our product or lowered cost	1 - 2 - 3 - 4 - 5

	Disagree Agree

Please evaluate the *knowledge* your firm gained from this supplier

We have learned something new from the interactions with this supplier in the project	1 - 2 - 3 - 4 - 5 Disagree Agree
Solutions developed during the interactions with this supplier were later used in other projects	1 - 2 - 3 - 4 - 5 Disagree Agree

<u>2. Supplier involvement strategy</u>
This supplier's level of design responsibility

during the early stages (for example the concept and specification stages) of the final product is	1 - 2 - 3 - 4 - 5 Low High
during the middle stages (for example the detailed engineering stage) of the final product is	1 - 2 - 3 - 4 - 5 Low High
during the later stages (for example process engineering/manufacturing) of the final product is	1 - 2 - 3 - 4 - 5 Low High

During the project, *when* does your firm *start* to involve the supplier?
[ ] the idea generating and project planning stage
[ ] model building and detailed design
[ ] prototype building or later

Please assess the *governance structure* for this joint project between your firm and the supplier (please check all the apply)
[ ] the two firms establish *a joint venture* in developing the product
[ ] one firm takes *a minority equity* position in the other
[ ] the two firms work together according to *unidirectional agreements*, such as licensing, second-sourcing, and distribution agreements, and *bidirectional agreements*, such as joint contracts and technology exchange agreements

<u>3. Manufacturing party</u>
Who is the manufacturing party for this product?
[ ] Our firm
[ ] Supplier ***
[ ] A third-party manufacturer
[ ] None of the above. Please specify

____

<u>4. Product Complexity</u>
Please evaluate the complexity of the product

The number of components in this product is much more than that in similar or substitute products	1 - 2 - 3 - 4 - 5 Disagree Agree
The product design required a higher number of interfaces than for similar or substitute products	1 - 2 - 3 - 4 - 5 Disagree Agree
The components for the product are more difficult to modularize than components for similar or substitute products	1 - 2 - 3 - 4 - 5 Disagree Agree
The level of expertise required for the design of the new product is high and more differentiated	1 - 2 - 3 - 4 - 5

than for similar or substitute products	Disagree Agree

5 Project objective novelty

The "beginning of the project" is defined as the time by which the major technological approach had been chosen and project go-ahead was given.

A company may have high or low experience in achieving a particular project objective. For example, some firms have great experience in producing low-cost products. In this case, if a firm had low unit-cost as a project objective, this firm has great experience with the unit-cost objective for this project.

At the beginning of the project, how much *experience* did your company have with:

the product performance objective	1 - 2 - 3 - 4 - 5 No Experience Some Experience Great Experience
the unit-cost objective	1 - 2 - 3 - 4 - 5 No Experience Some Experience Great Experience
the development schedule objective	1 - 2 - 3 - 4 - 5 No Experience Some Experience Great Experience

6. Technological uncertainty

Please assess the *newness* of the technologies to your company as perceived by the project group *at the beginning of the project.*

How new, on average, were the *product modules*?	1 - 2 - 3 - 4 - 5 Not new at all Somewhat new Completely new
How new was the *product configuration*[1]?	1 - 2 - 3 - 4 - 5 Not new at all Somewhat new Completely new
Overall, how new were the *product technologies* to be employed in this project?	1 - 2 - 3 - 4 - 5 Not new at all Somewhat new Completely new
How new, on average, were the individual *manufacturing stages*[2]?	1 - 2 - 3 - 4 - 5 Not new at all Somewhat new Completely new
How new was the *process layout*[3]?	1 - 2 - 3 - 4 - 5 Not new at all Somewhat new Completely new
Overall, how new were the *manufacturing technologies* to be employed with this project?	1 - 2 - 3 - 4 - 5 Not new at all Somewhat new Completely new

7. Inter-firm collaboration **outside** this project

---

[1] A product is made up of major subsections called *modules*. Modules may be subassemblies, subsystems, major components, etc. The way modules are linked together is the *product configuration*, also called product architecture or system design.

[2] The manufacturing process is made up of major individual *manufacturing stages*. A manufacturing stage can be a fabrication, machining, assembly, or packaging process.

[3] The order of the manufacturing stages, and linkages among the stages, constitutes the *process layout*.

Our firm works with this supplier on joint projects tailed to our respective needs.	1 - 2 - 3 - 4 - 5 Disagree Agree
Our firm works with the supplier to exploit unique opportunities.	1 - 2 - 3 - 4 - 5 Disagree Agree
Both our firm and the supplier are looking for synergetic ways to do business together.	1 - 2 - 3 - 4 - 5 Disagree Agree

8. Idiosyncratic investments

If our relationship with the supplier were to end, both firms would waste a lot of knowledge that's tailored to our relationship.	1 - 2 - 3 - 4 - 5 Disagree Agree
If either our firm or the supplier were to switch to a competitive buyer or vendor, it would lose a lot of the investments made in the present relationship.	1 - 2 - 3 - 4 - 5 Disagree Agree
Both our firm and the supplier have invested a great deal in building up our joint business.	1 - 2 - 3 - 4 - 5 Disagree Agree

9. How many people from your firm were actively on the project team?
[ ] less than or equal with 5,
[ ] between 5 and 15,
[ ] between 15 and 30,
[ ] between 30 and 50,
[ ] greater than 50.

10. Which country do *most of the people* from your firm involved in the project *come from*?

____

11. Which country is *the project team* from your firm *located* during the project most of the time?

____

12. Which country is *your firm's headquarter located* in? _________________________

13. How many people from the supplier were actively involved in the project?
[ ] less than or equal with 5,
[ ] between 5 and 15,
[ ] between 15 and 30,
[ ] between 30 and 50
[ ] greater than 50.

14. Which country do *most of the people* from the supplier involved in the project *come from*?

____

15. Which country are *people from the supplier located* during the project most of the time?

____

16. Which country is *the supplier's headquarter located* in? ________________________

17. Describe the business unit to which your answers apply:
[ ] Entire company
[ ] Division or group level
[ ] Process-based organization
[ ] Plant level

18. Please circle the following NAICS (North American Industry Classification System) category matching your company's primary industry. If you are not sure, please write down your company's industry.

311 Food Manufacturing	326 Plastics and Rubber Products Manufacturing
312 Beverage and Tobacco Product Manufacturing	327 Nonmetallic Mineral Product Manufacturing
313 Textile Mills	331 Primary Metal Manufacturing
314 Textile Product Mills	332 Fabricated Metal Product Manufacturing
315 Apparel Manufacturing	333 Machinery Manufacturing
316 Leather and Allied Product Manufacturing	334 Computer and Electronic Product Manufacturing
321 Wood Product Manufacturing	335 Electrical Equipment, Appliance, and Component Manufacturing
322 Paper Manufacturing	336 Transportation Equipment Manufacturing
323 Printing and Related Support Activities	337 Furniture and Related Product Manufacturing
324 Petroleum and Coal Products Manufacturing	3391 Medical Equipment and Supplies Manufacturing
325 Chemical Manufacturing	3399 Other Miscellaneous Manufacturing

19. What was the approximate number of employees at your company during the year when the final product was manufactured?

________________Full Time Equivalent Employees

20. What were the approximate annual sales for your company in the year the final product was manufactured?

________________ (thousands of US Dollars)

21a. How many years has your company been in business?
____

21b. How many years has your operation been functioning?
____

22. Which functional department do you come from in your firm?
[ ] Marketing
[ ] Engineering
[ ] Manufacturing
[ ] Purchasing
[ ] Others. Please specify ________________________________

23 What is your role in the product development project? (please check all that apply)
[ ] Project manager
[ ] Design engineer
[ ] Manufacturing engineer
[ ] Others, please specify ____

24. How knowledgeable did you feel answering this questionnaire?

[ ] Very knowledgeable
[ ] Above average
[ ] Average
[ ] Below average
[ ] Not knowledgeable

If you want us to send you a summary of our findings, please provide your email address or postal address. It will be kept strictly confidential.

Name	
Job Title	
Business Unit (if applicable)	
Company	
Address	
Phone	
E-mail	

THANK YOU!

Section 1

W. P. CAREY SCHOOL of BUSINESS

ARIZONA STATE UNIVERSITY

Coordination in buyer-supplier product design-Part 2

Many manufacturers are outsourcing design activities to suppliers, and suppliers are playing an increasingly important role in providing product and process innovations. The main purpose of this study is to investigate how design teams of a buyer firm and a supplier firm interact and coordinate in new product development. We hypothesize that different modes of inter-firm alignment will work better or worse, depending on characteristics of the project. Knowledge from this study will help project managers plan how best to coordinate design teams that involve collaboration between two organizations.

This survey is being conducted by researchers at the W. P. Carey School of Business, Arizona State University. The survey is composed by two parts, requiring information on a recent instance where your business unit collaborated with an external supplier on the design of a new product. The first part has been filled by a major project member from your firm participating in the collaboration. Your contact information was also provided by this project member.

This part of the survey seeks information on communication and decision making between people from your firm and a supplying firm in a new product development project. It also inquires about the goals of people from the two firms. Finally it asks about how people from the two firms interact on a daily basis.

At your request, a copy of the research findings will be sent to you, allowing you to benchmark your product development practices with those of other companies. Simply indicate your interest at the end of the survey.
All of your answers will be kept strictly confidential. No individual or company will be identified. Only summary data and aggregate results from multiple firms will be published. You have the right to skip any question you choose not to answer. However, we ask that you answer all questions to the best of your ability, as incomplete surveys can create serious problems with regard to data analysis. If you are not sure of an answer to a question, please provide your best estimate.
This questionnaire can be completed in about 10 to 15 minutes.
Participation in this study is completely voluntary.

We will be happy to answer any questions or concerns you may have. Please contact:

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Arizona State University
(480) 236 - 9588
kevin.dooley@asu.edu

Tingting Yan
Ph.D. Candidate-Supply Chain Management
W. P. Carey School of Business
Arizona State University
(831) 295 - 4120
tingting.yan@asu.edu

In answering all the questions below
-Please consider the following collaboration instance between your business unit and an external supplier firm on developing a new product:

Project name: ______________________________

Product name: ___________________________

Supplier name: ____

In which year the project started: ______________

Section 2: Inter-firm interaction

1. Communication

Please assess how people from your firm communicated with people from the supplier in the project:

Communication was frequent	1 - 2 - 3 - 4 - 5 Disagree Agree
Communication was intensive	1 - 2 - 3 - 4 - 5 Disagree Agree
Visual (face-to-face, video-conference, etc.) modes of communication were used	1 - 2 - 3 - 4 - 5 Disagree Agree
Audio (telephone) modes of communication were used	1 - 2 - 3 - 4 - 5 Disagree Agree
Electronic (email, EDI) modes of communication were used	1 - 2 - 3 - 4 - 5 Disagree Agree

2. Decision making process

2a. Hierarchy of authority

Please assess how people from your firm and the supplier, *when interacting with each other*, make decisions in the project:

There can be little action taken here until supervisors, from either our firm or the supplier or both, approves a decision	1 - 2 - 3 - 4 - 5 Disagree Agree
An engineer, from either our firm or the supplier, who wanted to make his own decisions would be quickly discouraged	1 - 2 - 3 - 4 - 5 Disagree Agree
Even small matters had to be referred to someone higher up, in either our firm or the supplier or both, for a final answer	1 - 2 - 3 - 4 - 5 Disagree Agree
I had to ask my boss before I do almost anything.	1 - 2 - 3 - 4 - 5 Disagree Agree
Any decision I made has to have my boss' approval.	1 - 2 - 3 - 4 - 5 Disagree Agree

2b. Participative decision making

If we have a decision to make, members from both my firm and from the supplier are involved in solving it.	1 - 2 - 3 - 4 - 5 Disagree Agree

In the project, opinions of members from both my firm and from the supplier get listened to.	1 - 2 - 3 - 4 - 5 Disagree Agree
In the project, we tell members from the supplier the way we are feeling.	1 - 2 - 3 - 4 - 5 Disagree Agree

3. Formalization

Please assess the extent formal rules were used when people from your firm *interact* with the supplier in the project:

To what degree were rules and procedures, specifying how people from your firm and the supplier communicate and make decisions, *formalized* via documents?	1 - 2 - 3 - 4 - 5 Not at all Somewhat Completely
To what degree were formal rules and procedures, specifying how people from your firm and the supplier communicate and make decisions, *actually followed*?	1 - 2 - 3 - 4 - 5 Not at all Somewhat Completely
To what degree were formal progress reviews, involving people from your firm and the supplier, held (sometimes called design, gate, phase, or stage reviews)?	1 - 2 - 3 - 4 - 5 Not at all Somewhat Completely

4. Inter-firm interdependence

"One firm" and "the other firm" mentioned in 4a below refer to either your firm or the supplier firm.

4a. Design task interdependence

Throughout the project,

People from one firm had to depend on people from the other firm to obtain the materials, people, or information needed to do their work	1 - 2 - 3 - 4 - 5 Disagree Agree
After people from one firm finished their part of the job, they had to rely on the other firm to perform the next steps in the process before the total task was completed	1 - 2 - 3 - 4 - 5 Disagree Agree
Very often one firm's job required that it check with the other firm while doing its major tasks	1 - 2 - 3 - 4 - 5 Disagree Agree

4b. Component-Product interdependence

On average, a design change in this product was expected to significantly impact the design effort for other products, which share design interfaces with the focal product.	1 - 2 - 3 - 4 - 5 Disagree Agree

4c. Design-manufacturing interdependence

A design change in the product technologies was expected to significantly impact the design effort for the manufacturing technologies	1 - 2 - 3 - 4 - 5 Disagree Agree

5. <u>Goal congruence</u>

Please consider both *project performance goals*, such as cost, schedule, etc., and *product performance goals,* such as weight, size, speed, etc.

At the time when we *started to involve* the supplier in the project, we

had goals that were in conflict with goals of the supplier	1 - 2 - 3 - 4 - 5 Disagree Agree
had compatible goals with the supplier	1 - 2 - 3 - 4 - 5 Disagree Agree
supported the supplier's goals and the supplier supported our goals	1 - 2 - 3 - 4 - 5 Disagree Agree
felt it is highly likely to realize both our goals and the supplier's goals	1 - 2 - 3 - 4 - 5 Disagree Agree

6. <u>Trust</u>

Please assess the relationship between people from your firm and those from the supplier in the project:

Our promises to each other were reliable	1 - 2 - 3 - 4 - 5 Disagree Agree
We were very honest in dealing with each other	1 - 2 - 3 - 4 - 5 Disagree Agree
We trusted each other	1 - 2 - 3 - 4 - 5 Disagree Agree
We could go out of our way to help each other out	1 - 2 - 3 - 4 - 5 Disagree Agree
We considered each other's interests when problems arise	1 - 2 - 3 - 4 - 5 Disagree Agree

7. <u>Opportunistic behaviors</u>

When *a problem occurred* in the project, how often will people from the supplier do the following?

They made hollow promises	1 - 2 - 3 - 4 - 5 Hardly ever Very often
They were aloof toward us	1 - 2 - 3 - 4 - 5 Hardly ever Very often
They "window dressed" their efforts to improve	1 - 2 - 3 - 4 - 5 Hardly ever Very often
They expected us to pay for more than our fair share of the costs to correct the problem	1 - 2 - 3 - 4 - 5 Hardly ever Very often
They were unwilling to accept responsibility	1 - 2 - 3 - 4 - 5 Hardly ever Very often
They made false accusations	1 - 2 - 3 - 4 - 5 Hardly ever Very often
They provided false information	1 - 2 - 3 - 4 - 5 Hardly ever Very often
They failed to provide proper notification	1 - 2 - 3 - 4 - 5 Hardly ever Very often

8. Collaboration process

Please assess the nature of the *daily interaction* between members from your firm and the supplier:

Between the buyer and the supplier members, important ideas and information were exchanged openly	1 - 2 - 3 - 4 - 5 Disagree Agree
Between the buyer and the supplier members, people adapted well to each other.	1 - 2 - 3 - 4 - 5 Disagree Agree
Between the buyer and the supplier members, the general atmosphere was cooperative.	1 - 2 - 3 - 4 - 5 Disagree Agree

We were satisfied with the *timeliness* in which information was made available by members from the supplier	1 - 2 - 3 - 4 - 5 Disagree Agree
We were satisfied with the *accuracy* of the information provided by members from the supplier	1 - 2 - 3 - 4 - 5 Disagree Agree

Members from both firms assumed full responsibility for achieving the project's objectives	1 - 2 - 3 - 4 - 5 Disagree Agree
Members from both firms fully contributed to carrying the project's workload	1 - 2 - 3 - 4 - 5 Disagree Agree
Members from both firms were fully committed to reaching the project objectives	1 - 2 - 3 - 4 - 5 Disagree Agree

Strengths and weaknesses of members from our firm and the supplier are recognized.	1 - 2 - 3 - 4 - 5 Disagree Agree
Members from both firms were contributing to the project in accordance with their specific potential.	1 - 2 - 3 - 4 - 5 Disagree Agree
Imbalance of contributions from our firm and the supplier caused conflicts in the project.	1 - 2 - 3 - 4 - 5 Disagree Agree

The different job and work activities conducted by members from the two firms fit together very well	1 - 2 - 3 - 4 - 5 Disagree Agree
People from the two firms who had to work together did their jobs properly and efficiently	1 - 2 - 3 - 4 - 5 Disagree Agree
All related things and activities were well timed in the everyday routine of the innovation process	1 - 2 - 3 - 4 - 5 Disagree Agree
The work assignments of the people from the two firms were well planned	1 - 2 - 3 - 4 - 5 Disagree Agree

9. Capability complementarity

During the project, we and people from the supplier

contributed different resources to the project that helped us achieve a better product design.	1 - 2 - 3 - 4 - 5 Disagree Agree
had complementary strengths that were useful to the project	1 - 2 - 3 - 4 - 5 Disagree Agree
had separate capabilities that, when combined together, enabled us to achieve a better product design beyond our individual reach.	1 - 2 - 3 - 4 - 5 Disagree Agree

<u>Section 3: Project information</u>

<u>10. Task relevant expertise</u>

Project members (from both your firm and the supplier)

were knowledgeable about designing the product	1 - 2 - 3 - 4 - 5 Disagree Agree
were competent in designing the product	1 - 2 - 3 - 4 - 5 Disagree Agree
were expert in designing the product	1 - 2 - 3 - 4 - 5 Disagree Agree
were well trained in designing the product	1 - 2 - 3 - 4 - 5 Disagree Agree
were experienced in designing the product	1 - 2 - 3 - 4 - 5 Disagree Agree

<u>11. Physical proximity</u>

How many people from the supplier, who were involved in the project, were conveniently located near you in the project?

[ ] None
[ ] Less than half
[ ] More than half
[ ] All

13. Project organization

The project team, composed by members either from *your firm alone* or from *both your firm and the supplier*

Was composed by members from multiple functions, such as marketing, R&D, production, etc.	1 - 2 - 3 - 4 - 5 Disagree Agree
Was accountable for the project from beginning to end	1 - 2 - 3 - 4 - 5 Disagree Agree
Was dedicated to the project (not to multiple projects)	1 - 2 - 3 - 4 - 5 Disagree Agree
Was led by a strong and dedicated leader	1 - 2 - 3 - 4 - 5 Disagree Agree
Had top management support	1 - 2 - 3 - 4 - 5 Disagree Agree

Section 4: Background Information

1. Which functional department do you come from in your firm?

[ ] Marketing
[ ] Engineering
[ ] Manufacturing
[ ] Purchasing
[ ] Others. Please specify ______________________________

2. What is your role in the product development project? (please check all that apply)

[ ] Project manager
[ ] Design engineer

[ ] Manufacturing engineer
[ ] Others, please specify ____

3. How knowledgeable did you feel answering this questionnaire?
[ ] Very knowledgeable
[ ] Above average
[ ] Average
[ ] Below average
[ ] Not knowledgeable

4. Do you have any other comments about how the buyer and supplier coordinated during the project?

If you want us to send you a summary of our findings, please provide your email address or postal address. It will be kept strictly confidential.

Name	
Job Title	
Business Unit (if applicable)	
Company	
Address	
Phone	
E-mail	

THANK YOU!

第一部份

W. P. CAREY SCHOOL of BUSINESS

ARIZONA STATE UNIVERSITY

关于制造商和供应商在产品开发合作中的协调问题的研究

越来越多的原材料供应商正在参与到制造厂商的产品开发与设计中来。这些原材料供应商不再仅仅是提供现成的产品，而是通过提供最新的产品和制造工艺技术给制造厂，来提高新产品的设计质量和可制造性，以符合制造厂和最终客户的要求。但是，如果来自制造厂和供应商的不同设计人员的在完成各自项目任务时没有被有效的协调，重要的信息没有及时的沟通，往往会阻碍合作的顺利进行。

这份问卷的主要目的，就是在于研究来自制造厂商（买方）和供应商（买方）的设计人员之间应该如何有效的进行协调。通过这份问卷收集到的数据将用来验证我们的理论模型：买方和卖方之间的协调方式应该随着产品开发项目的结构特性而变化。这份研究的结果将有助于项目经理了解如何最有效的协调来自不同公司的设计人员，以最大化制造商和供应商在产品开发合作中的收益。

这份问卷是由美国亚利桑那大学凯丽商学院的研究人员设计的。问卷中的问题都围绕着贵公司（买方）与一个供应商合作产品开发的事件。该问卷由两部份组成，您现在看到的为第一部份。涉及到的问题包括与该供应商合作的这个项目最后的绩效，贵公司与该供应商的合作策略，以及产品的一些特性。

- 如果您需要，我们可以将这份研究的结果发送给您。这些结果将有助于贵公司将自己的产品开发流程与其他公司进行比较。您可以在问卷的末尾留下您的联系方式以及您有兴趣知道研究结果的意向。
- 您所有的回到都会严格保密。在这份问卷中提及的任何个人或者公司的信息都不会外传。在最后的研究中，我们只会用到来自所有问卷的累计和概括数据。
- 您有权利跳过任何问题。但是，我们希望您能够尽你的全力回答所有的问题，这样能够提高本研究结果的有效性。如果您对于哪一个问题不确定，请给出您最好的估计。
- 这份问卷可以在 5 到 10 分钟之内回答完毕。
- 参与这个研究完全是基于自愿原则。

如果您对这个研究有任何的问题，我们非常乐意为您提供解答。请联系：

Kevin Dooley,
博士，教授
供应链管理系
凯丽商学院

严婷婷
博士生候选人
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此问卷为整个研究的第一部分。第二部分将会由您在下面制定的一位项目组成员填写。

在回答以下所有的问题中：
———请选择一个最近一年完成的产品开发项目。在此项目中，贵公司与一家供应商进行合作开发该产品。
———贵公司与该供应商的合作可以有很多表现形式。比如说，该供应商根据贵公司的特殊要求而对已有的产品进行设计和生产，或者贵公司在产品开发过程中听取该供应商对于产品设计和生产的意见，或者该供应商与贵公司一起合作开发该产品。
———您所有的回答都请围绕该项目和该供应商。

1. 请在以下空白处指明另外一位项目组成员，该成员必须积极的参与到该项目的主要阶段，并且是在该项目中与该供应商接触的主要联络人。此问卷的第二部分将由您所指定的这位成员来回答。
    a. 您在此问卷中的所有回到将对您所指定的这位项目成员严格保密。
    b. 如果您可以联系这位项目组成员，并邀请他/她回答第二部分的问卷，我们将非常感激。因为若没有这位您所指定的项目组成员对于第二部分问卷的回答，您在第一部分的回答也将无法进入最后的统计分析。

姓名：________________________________

邮件：________________________________

2. 为了让这位项目组成员清楚您在第一部分问卷中所选择的项目和供应商分别是什么，请尽可能多和详细的提供以下信息：

项目名称：____

产品名称：____

供应商名称：____

项目开始与结束日期:______________________________________

注：以下所有表格的每一行都代表一个独立的问题，请您尽最大可能回答。

1. 产品设计性能

最终的产品设计

质量很高	1 - 2 - 3 - 4 - 5 不同意 同意
完全符合尺寸设计要求 （dimensional integrity）	1 - 2 - 3 - 4 - 5 不同意 同意
完全符合耐用性设计要求 (durability)	1 - 2 - 3 - 4 - 5 不同意 同意
完全符合功能设计要求 (functionality)	1 - 2 - 3 - 4 - 5 不同意 同意
具有高度的可制造性 (manufacturability)	1 - 2 - 3 - 4 - 5 不同意 同意
符合最终客户的要求	1 - 2 - 3 - 4 - 5 不同意 同意

请评估该产品的开发流程：

开发该产品没有超过我们的项目经费预算	1 - 2 - 3 - 4 - 5 不同意 同意
开发该产品的成本一直控制的很低	1 - 2 - 3 - 4 - 5 不同意 同意
产品开发的时间没有超过我们预期的开发时间	1 - 2 - 3 - 4 - 5 不同意 同意
产品开发的整个流程都按预期的时间完成	1 - 2 - 3 - 4 - 5 不同意 同意

请评价该项目的开发成本和开发周期的目标的难易程度

项目成本预算的目标非常难以达到	1 - 2 - 3 - 4 - 5 不同意 同意
项目开发时间的目标非常难以达到	1 - 2 - 3 - 4 - 5 不同意 同意
产品设计质量目标非常难以达到	1 - 2 - 3 - 4 - 5 不同意 同意
尺寸设计目标非常难以达到	1 - 2 - 3 - 4 - 5 不同意 同意
耐用性设计目标非常难以达到	1 - 2 - 3 - 4 - 5 不同意 同意
功能设计目标非常难以达到	1 - 2 - 3 - 4 - 5 不同意 同意
可制造性设计目标非常难以达到	1 - 2 - 3 - 4 - 5 不同意 同意
最终客户的设计要求非常难以达到	1 - 2 - 3 - 4 - 5 不同意 同意

请评价该供应商对于该项目的贡献

与该供应商的合作提高了该产品的技术性能	1 - 2 - 3 - 4 - 5 不同意 同意
该供应商的建议提高了产品质量或者降低了产品成本	1 - 2 - 3 - 4 - 5 不同意 同意

请评估贵公司通过与该供应商合作所学到的知识

通过与该供应商合作，我们学到了新的技术或者知识	1 - 2 - 3 - 4 - 5 不同意 同意
在与该供应商合作过程中开发出的新解决方案后来被用于本公司其他的项目	1 - 2 - 3 - 4 - 5 不同意 同意

该供应商在项目各个阶段中的设计开发任务量

在该产品开发项目早期阶段（比如概念设计，初步设计，和系统设计阶段）	1 - 2 - 3 - 4 - 5 低 高
在该产品设计开发中期阶段（比如详细设计阶段）	1 - 2 - 3 - 4 - 5 低 高
在该产品开发后期阶段（比如工艺流程设计和产品生产阶段）	1 - 2 - 3 - 4 - 5 低 高

在项目中，贵公司在哪个阶段开始与该供应商合作？

【 】 设计初步概念产生和项目计划阶段

【 】 系统设计和详细设计阶段

【 】 工艺流程设计，模具制造以及生产阶段

请评估贵公司与该供应商之间是在何种方式之下进行合作的？（请选择所有符合的选项）

【 】 两个公司成立了一个联合投资公司来开发这个新产品

【 】 一个公司掌握了另一个公司的少数股权

【 】 两个公司通过单向协议，比如许可协议，外包和分销协议，或者双向协议，比如合同和技术交换协议

该产品的制造方是：

【 】 贵公司

【 】 该供应商

【 】 一个第三方制造商

【 】 其他。请说明____________________________________

4. 产品复杂度

请评估该产品的复杂度

该产品有非常多的零部件（与贵公司的其他类似产品的平均零部件数量相比较）	1 - 2 - 3 - 4 - 5 不同意 同意
该产品的零部件之间的互相依存性强（若一个零部件的设计出现改动，很多其他零部件会受到影响）	1 - 2 - 3 - 4 - 5 不同意 同意

该产品的零部件之间的差异很大（同类或者相似的零部件很少）	1 - 2 - 3 - 4 - 5 不同意 同意

5 项目目标的新颖性

“项目的开始”是指主要的技术方法应经被选定，并且项目已经被公司管理层正式批准的时间。

一个公司对于一个项目目标可能富有或者缺乏经验。比方说，有些公司对于设计生产低成本的产品很有经验。这样，如果低成本是项目的一个目标，那么这些公司就对于该目标有丰富的经验，而该目标对于这些公司就不新颖。

在项目的开始，贵公司对于该项目的以下目标有多少经验：

产品性能目标	1 - 2 - 3 - 4 - 5 没有经验 有些经验 丰富的经验
产品单位成本目标	1 - 2 - 3 - 4 - 5 没有经验 有些经验 丰富的经验
产品开发流程（时间和开发成本）目标	1 - 2 - 3 - 4 - 5 没有经验 有些经验 丰富的经验

6. 技术的创新程度

在项目开始时，请评估该项目中的产品和流程技术的创新程度

该产品的每个模块的设计有多新？	1 - 2 - 3 - 4 - 5 完全不新 有一点新 完全是新的
产品构造（各个零部件之间的依附关系）有多新？	1 - 2 - 3 - 4 - 5 完全不新 有一点新 完全是新的
整体来说，该项目中的产品技术有多新？	1 - 2 - 3 - 4 - 5 完全不新 有一点新 完全是新的
该产品制造流程的各个阶段的工艺有多新？	1 - 2 - 3 - 4 - 5 完全不新 有一点新 完全是新的
该产品的各个制造阶段之间的顺序和依附关系有多新？	1 - 2 - 3 - 4 - 5 完全不新 有一点新 完全是新的
整体来说，该项目中的产品工艺技术有多新？	1 - 2 - 3 - 4 - 5 完全不新 有一点新 完全是新的

7. 贵公司与该供应商的其他合作经历

我们公司与该供应商经常在各种项目中进行合作来满足我们各自的需求	1 - 2 - 3 - 4 - 5 不同意 同意
我们公司经常与该供应商进行合作来抓住各种商机	1 - 2 - 3 - 4 - 5 不同意 同意
我们公司与该供应商都在寻求双赢的方式来维系两公司之间的关系	1 - 2 - 3 - 4 - 5 不同意 同意

8. 贵公司与该供应商之间的非通用性投资

公司之间的非通用性投资是两公司为了提高双方交易的效率和有效性，而由一方或双方进行的投资，当两公司的交易关系结束时，这些投资的价值将会大幅降低。

如果我们与该供应商的买卖关系终止，双方都会损失很多为了维系两公司的交易关系所建立的知识体系（比如，该供应商的职员关于贵公司的一些特殊的工作流程的了解）	1 - 2 - 3 - 4 - 5 不同意 同意
如果我们公司或者该供应商选择另一个供应商或者买家，那么我们公司或者该供应商将会损失很多为了维系两公司关系所进行的投资（比如该供应商为了满足贵公司对于产品的某项特殊要求而购买的新生产设备）	1 - 2 - 3 - 4 - 5 不同意 同意
我们公司与该供应商都进行了大量的投资来构建和维系我们的关系	1 - 2 - 3 - 4 - 5 不同意 同意

9. 贵公司有多少人参与到这个项目中来？

【 】少于等于 5 人
【 】 5 人到 15 人之间
【 】 15 人到 30 人之间
【 】 30 人到 50 人之间
【 】 50 人以上

10. 贵公司参与到该项目中的大多数成员来自于哪个国家？

____

11. 在该项目进行的大部份时间，贵公司的项目组的大部份人员在哪个国家哪个省市？

____

12. 贵公司的总部在哪个国家？

____

13. 该供应商有多少人参与到这个项目中来？

【 】少于等于 5 人
【 】 5 人到 15 人之间
【 】 15 人到 30 人之间
【 】 30 人到 50 人之间
【 】 50 人以上

10. 该供应商参与到该项目中的大多数成员来自于哪个国家？

____

11. 在该项目进行的大部份时间，该供应商的项目组的大部份人员在哪个国家哪个省市？

____

12. 该供应商的总部在哪个国家？

____

17. 该项目的级别是
【 】 整个公司范围的
【 】 部门级别
【 】 工厂级别
18． 请用圆圈选择贵公司所在的产业类别。如果您不肯定，请写下您公司所在的产业。

311 食品制造	327 非金属矿产品制造
312 饮料和烟草产品制造	331 主要金属制造
313 纺织	332 五金加工制造
315 服装制造	333 机械制造
316 皮革和皮革制品制造	334 计算机和电子产品制造
321 木制品制造	335 电子设备，家用电器和部件制造
322 纸制造	336 运输设备制造
323 印刷和相关支持产业	337 家具和相关产品制造
324 石油和煤炭产品制造	3391 医疗设备和医疗用品制造
325 化工制造	3399 其他产品制造
326 塑料和橡胶制品制造	其他 _____________________________

19. 在该产品开始投入生产时，贵公司的正式全职雇员大概有多少人？

______________（人）

20. 在该产品开始投入生产时，贵公司的年销售额大概为多少万人民币？

______________ (万人民币)

21a 贵公司营业有多少年了？ ________________________________
21b 您所在的部门运作有多少年了？ ___________________________

22. 您所在的部门是
【】市场部
【】工程设计部
【】生产制造部
【】采购部
【】其他。请说明______________________

23 请说明您在该项目中的职位？（请选择所有合适的选项）
【】项目经理
【】产品设计工程师
【】工艺设计工程师
【】其他。请说明______________________

24. 您对于这份问卷中的问题的了解程度有多高（您对于您的回答的准确性有多大把握）？
【】非常了解（很大把握）
【】比较了解（比较大的把握）
【】一般的了解（一般）
【】不是太了解（不太大的把握）
【】很不了解（没有多少把握）

25. 您对于贵公司在与该供应商在此项目中的沟通协调还有其他的评价吗？

如果您希望我们给您发送一份这份研究的结果，请留下您的邮件地址或者是邮寄地址。所有的信息将会严格保密。

姓名	
工作职位	
部门	
公司	
地址	

电话	
邮件	

谢谢！

第二部份

W. P. CAREY SCHOOL of BUSINESS
ARIZONA STATE UNIVERSITY

关于制造商和供应商在产品开发合作中的协调问题的研究

越来越多的原材料供应商正在参与到制造厂商的产品开发与设计中来。这些原材料供应商不再仅仅是提供现成的产品，而是通过提供最新的产品和制造工艺技术给制造厂，来提高新产品的设计质量和可制造性，以符合制造厂和最终客户的要求。但是，如果来自制造厂和供应商的不同设计人员在完成各自的项目任务时没有被有效的协调，重要的信息没有及时的沟通，往往会阻碍合作的顺利进行。

这份问卷的主要目的，就是在于研究来自制造厂商（买方）和供应商（买方）的设计人员之间应该如何有效的进行协调。通过这份问卷收集到的数据将用来验证我们的理论模型：买方和卖方之间的协调方式应该随着产品开发项目的结构特性而变化。这份研究的结果将有助于项目经理了解如何最有效的协调来自不同公司的设计人员，以最大化制造商和供应商在产品开发合作中的收益。

这份问卷是由美国亚利桑那大学凯丽商学院的研究人员设计的。问卷中的问题都围绕着一次贵公司（买方）与一个供应商（卖方）合作产品开发的事件。该问卷由两部份组成，您现在看到的为第二部份。第一部分已经由贵公司的一位主要项目组成员围绕这次合作事件回答完毕，您的联系信息也是由这位项目组成员提供。第二部分涉及到的问题包括贵公司与该供应商合作过程中的通信和决策流程，两公司项目成员的目标结构，以及两公司的项目成员之间的合作方式。

- 如果您需要，我们可以将这份研究的结果发送给您。这些结果将有助于贵公司将自己的产品开发流程与其他公司进行比较。您可以在问卷的末尾留下您的联系方式以及您有兴趣知道研究结果的意向。
- 您所有的回答都会严格保密。在这份问卷中提及的任何个人或者公司的信息都不会外传。在最后的研究中，我们只会用到来自所有问卷的累计和概括数据。
- 您有权利跳过任何问题。但是，我们希望您能够尽你的全力回答所有的问题，这样能够提高本研究结果的有效性。如果您对于哪一个问题不确定，请给出您最好的估计。
- 这份问卷可以在 5 到 10 分钟之内回答完毕。
- 参与这个研究完全是基于自愿原则。

如果您对这个研究有任何的问题，我们非常乐意为您提供解答。请联系：

Kevin Dooley,	严婷婷
博士，教授	博士生候选人

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在回答以下所有的问题时，
———请围绕以下所说明的你所参与过的这个项目，在该项目中，贵公司与一供应商进行合作开发新产品。
———贵公司与该供应商的合作可以有很多表现形式。比如说，该供应商根据贵公司的特殊要求而对已有的产品进行设计和生产，或者贵公司在产品开发过程中听取该供应商对于产品设计和生产的意见，或者该供应商与贵公司一起合作开发该产品。

项目名称: ______________________________

产品名称: ___________________________

供应商名称: ____

项目开始和结束时间: ____

注：以下所有表格的每一行都代表一个独立的问题，请您尽最大可能回答。

1. 贵公司与该供应商的通信方式
请评估贵公司和该供应商之间在该项目中通信方式：

1-1. 通信很频繁	1 - 2 - 3 - 4 - 5 不同意 同意
1-2. 每次通信时间很长	1 - 2 - 3 - 4 - 5 不同意 Agree
1-3. 我们使用了基于可视化的通信方式（比如面对面，视频会议，等）	1 - 2 - 3 - 4 - 5 不同意 同意
1-4. 我们使用了基于声音的通信方式（比如电话，等）	1 - 2 - 3 - 4 - 5 不同意 同意
1-5. 我们使用了电子通信方式（比如电子数据传输，传真，邮件，等）	1 - 2 - 3 - 4 - 5 不同意 同意

2. 贵公司与该供应商的决策方式
2a. 请评估贵公司在与该供应商合作过程中是如何做决策的？

项目里的大部分行动和决策都需要得到我们公司或者供应方公司的高层领导批准	1 - 2 - 3 - 4 - 5 不同意 同意
我们不鼓励项目组成员，不管是来自我们公司还是该供应商，自由做决策	1 - 2 - 3 - 4 - 5 不同意 同意
即便是项目中发生的很小的事件，也需要高层领导，不管是我们公司还是供应商公司，来做决策	1 - 2 - 3 - 4 - 5 不同意 同意
在项目中，我做任何事情都需要征求我的上级的意见	1 - 2 - 3 - 4 - 5 不同意 同意
在项目中，我做任何决策都需要得到我的上级的批准	1 - 2 - 3 - 4 - 5 不同意 同意

2b. 决策参与性

在项目中，如果我们需要做一个决策，我们公	1 - 2 - 3 - 4 - 5

司和该供应商的成员都会参与	不同意 同意
在项目中，来自我们公司和供应商的意见都会被听取	1 - 2 - 3 - 4 - 5 不同意 同意
在项目中，来自两个公司的成员经常交流各自的想法	1 - 2 - 3 - 4 - 5 不同意 同意

3. 贵公司和该供应商合作的规条化程度

请评估在该项目中，自两个公司的项目成员之间接触和交流的规条化程度

关于两公司项目成员之间应该如何接触，交流和做决策的条例和流程在多大程度上被制定成了正式的文件？	1 - 2 - 3 - 4 - 5 完全没有 一定程度 完全地
这些条例和流程在多大程度上被项目成员所遵守？	1 - 2 - 3 - 4 - 5 完全没有 一定程度 完全地
在该项目中，由两公司项目成员共同参加的正式的项目阶段总结会议在多大程度上被举行？	1 - 2 - 3 - 4 - 5 完全没有 一定程度 完全地

4. 贵公司与该供应商在项目中的互相依赖性

在 4a 中提到的“一方”和“另一方”指贵公司或者该供应商

4a. 设计任务的互相依赖性

在整个项目中：

来自一方的项目成员得依靠来自另一方的项目成员来取得完成项目任务所需要的原材料，人员，或者信息	1 - 2 - 3 - 4 - 5 不同意 同意
当一方的成员完成手头的任务后，在另一方的成员完成整个流程中的下一步之前，该方成员无法进行下一步	1 - 2 - 3 - 4 - 5 不同意 同意
一方的成员在进行项目任务时，经常需要与另一方的成员进行接触以取得相关信息	1 - 2 - 3 - 4 - 5 不同意 同意

4b. 该产品与其他产品之间的互相依赖性

总体说来，这个产品的设计变动将会影响到很多与之共有设计接口的产品的设计	1 - 2 - 3 - 4 - 5 不同意 同意

4c. 设计制造相关性

这个产品的设计变动将会显著的影响到制造工艺的设计	1 - 2 - 3 - 4 - 5 不同意 同意

5. 贵公司与该供应商的目标协调性

请既考虑项目目标，比如开发成本，开发时间，等，也考虑产品绩效目标，比如重量，尺寸，速度，功能，等。

在我们开始与该供应商在此项目中合作时，我们

与该供应商有相冲突的目标	1 - 2 - 3 - 4 - 5

	不同意　　　　同意
与该供应商的目标一致	1 - 2 - 3 - 4 - 5 不同意　　　　同意
支持该供应商的目标，该供应商也支持我们的目标	1 - 2 - 3 - 4 - 5 不同意　　　　同意
认为同时实现我们的目标和该供应商的目标的可能性很大	1 - 2 - 3 - 4 - 5 不同意　　　　同意

6. 信任

请评估贵公司的项目组成员与来自该供应商的成员在项目中的关系：

我们互相之间的承诺都是信实的	1 - 2 - 3 - 4 - 5 不同意　　　　同意
我们之间都是以诚待人	1 - 2 - 3 - 4 - 5 不同意　　　　同意
我们互相信任	1 - 2 - 3 - 4 - 5 不同意　　　　同意
我们互相之间都想法设法的帮助对方	1 - 2 - 3 - 4 - 5 不同意　　　　同意
当出现问题时，我们都考虑对方的利益	1 - 2 - 3 - 4 - 5 不同意　　　　同意

7. 机会主义行为

当项目合作中出现问题时，来自该供应商的项目成员会经常有以下行为吗？

他们做虚假承诺	1 - 2 - 3 - 4 - 5 几乎从来没有　　　　常常
他们态度冷淡	1 - 2 - 3 - 4 - 5 几乎从来没有　　　　常常
他们仅仅只是摆出解决问题的姿态，但是没有实际行动	1 - 2 - 3 - 4 - 5 几乎从来没有　　　　常常
他们期望在解决问题的过程中，我方担负超过我们所应当担负的开销	1 - 2 - 3 - 4 - 5 几乎从来没有　　　　常常
他们不愿意对问题负起责任	1 - 2 - 3 - 4 - 5 几乎从来没有　　　　常常
他们作出错误的指责	1 - 2 - 3 - 4 - 5 几乎从来没有　　　　常常
他们提供错误的信息	1 - 2 - 3 - 4 - 5 几乎从来没有　　　　常常
他们没有提供适时的通知和提醒	1 - 2 - 3 - 4 - 5 几乎从来没有　　　　常常

8. 合作过程

请评估来自贵公司和该供应商的项目成员的日常接触和交流：

双方成员毫无保留的交流重要的信息和	1 - 2 - 3 - 4 - 5

观点	不同意　　　　　　同意
双方成员对于另一方的变化能作出迅速的调整和适应	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
双方成员是在和睦的气氛下进行合作的	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意

我们对于该供应商的项目成员所提供的信息的及时性感到满意	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
我们对于该供应商的项目成员所提供的信息的准确性感到满意	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意

双方公司的项目成员都为了实现项目目标而负起全部的责任	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
双方公司的项目成员都尽力完成项目所要求的工作	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
双方公司的项目成员都为了完成项目目标而尽心尽力	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意

两公司的项目成员对于各自的优势和劣势有充分的认识	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
两公司的项目成员能够根据各自的能力对项目作出相应的贡献	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
两公司的成员对于项目的贡献不平均，这种不平均导致了一些项目中的冲突	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意

由贵公司的项目成员所完成的项目任务与由该供应商的项目成员所完成的项目任务之间配合衔接的很好	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
来自两个公司的项目成员在互相合作时完满和高效的完成了他们的工作	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
在项目进行的每一天，所有相关联的任务之间在时间和空间上都衔接的很好	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
两公司参与该项目的成员的项目任务是周详的计划过的，因此各个独立任务之间协调的很好	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意

9. 贵公司与该供应商的优势互补性

在项目中，我们和来自该供应商的项目成员

对项目贡献了不同的资源，这种资源互补性帮助我们得到了更好的产品设计	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
各自强项的互补性提高了项目的绩效	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意
有不同的能力，当我们将这些不同的能力用在项目中时，我们能够设计出比我们双方各自单独设计时更好的产品	1 - 2 - 3 - 4 - 5 不同意　　　　　　同意

10. 项目成员的设计能力
来自贵公司和该供应商的项目成员

有丰富的产品设计知识	1 - 2 - 3 - 4 - 5 不同意 同意
产品设计能力很强	1 - 2 - 3 - 4 - 5 不同意 同意
受过良好的产品设计专业训练	1 - 2 - 3 - 4 - 5 不同意 同意
是产品设计专家	1 - 2 - 3 - 4 - 5 不同意 同意
产品设计经验丰富	1 - 2 - 3 - 4 - 5 不同意 同意

11. 在项目中两公司项目成员所在地的距离
在此项目中，如果您需要与该供应商的项目成员进行面对面的沟通，来自该供应商的项目组全部成员中有多少人所在的地方您可以方便的马上到达的？
【 】没有人
【】少于一半
【 】多于一半
【】全部

12. 项目组织结构
来自贵公司和该供应商的项目成员

来自各个不同部门，比如市场部，研发部，生产部，采购部，等等	1 - 2 - 3 - 4 - 5 不同意 同意
从开始到结束都对此项目负责	1 - 2 - 3 - 4 - 5 不同意 同意
只专职于这一个项目（没有同时参与多个项目）	1 - 2 - 3 - 4 - 5 不同意 同意
由一个有能力并且全心投入的项目经理带领	1 - 2 - 3 - 4 - 5 不同意 同意
得到公司高层的支持	1 - 2 - 3 - 4 - 5 不同意 同意

背景信息

1. 您所在的部门是
【】市场部
【】工程设计部
【】生产制造部
【】采购部
【】其他。请说明______________________

2 请说明您在该项目中的职位？（请选择所有合适的选项）
【】项目经理
【】产品设计工程师
【】工艺设计工程师
【】其他。请说明______________________

3. 您对于这份问卷中的问题的了解程度有多高（您对于您的回答的准确性有多大把握）？
【】非常了解（很大把握）
【】比较了解（比较大的把握）
【】一般的了解（一般）
【】不是太了解（不太大的把握）
【】很不了解（没有多少把握）

4. 您对于贵公司在与该供应商在此项目中的沟通协调还有其他的评价吗？

如果您希望我们给您发送一份这份研究的结果，请留下您的邮件地址或者是邮寄地址。所有的信息将会严格保密。

姓名	
工作职位	
部门	
公司	
地址	
电话	
邮件	

谢谢！

APPENDIX B

[SUPPORT DATA]

Table B-1 Items descriptive statistics

Construct/items	Mean	Standard Deviation	Skewness	Kurtosis
Communication Intensity				
ci1	4.03	.98	-.96	-.60
ci2	3.60	1.13	-.46	-.58
Goal Congruence				
gc1	3.79	1.26	-.75	-.61
gc2	4.02	.98	-.98	.65
gc3	4.04	.97	-1.0	.77
gc4	3.90	1.05	-.90	.37
Task Interdependence				
ti1	3.88	1.12	-.91	.17
ti2	3.67	1.18	-.76	-.23
ti3	3.72	1.09	-.62	-.32
Collaboration Quality				
cq1	4.05	.95	-.88	.35
cq2	4.04	.89	-.80	.51
cq3	4.28	.78	-1.02	.93
cq4	3.70	1.06	-.64	-.25
cq5	3.82	1.05	-.63	-.41
cq6	4.02	1.02	-1.10	.84
cq7	4.04	.89	-1.11	1.15
cq8	4.23	.93	-1.37	1.92
cq9	3.85	.96	-.78	.52
cq10	4.04	.87	-1.02	1.46
cq11	3.62	1.35	-.66	-.82
cq12	3.94	.934	-.80	.510
cq13	3.98	.93	-.96	.99
cq14	3.57	1.01	-.50	-.90
cq15	3.47	1.07	-.39	-.38
Product Complexity				
pc1	2.86	1.31	.10	-1.05
pc2	3.07	1.27	-.06	-.99
pc3	2.98	1.29	.07	-1.02
pc4	3.46	1.19	-.45	-.63
Product Technology Novelty				
tn1	3.25	1.07	-.21	-.37
tn2	3.30	1.14	-.13	-.69
tn3	3.14	1.02	-.19	-.42
Process Technology Novelty				
tn4	2.83	1.14	.12	-.62
tn5	2.77	1.09	.26	-.44
tn6	2.77	1.12	.08	-.68
Coordination Efforts				

ce1	3.72	1.23	-.82	-.28
ce2	3.47	1.29	-.49	-.80
ce3	3.65	1.22	-.67	-.42
Idiosyncratic Investment				
ii1	2.94	1.35	.00	-1.20
ii2	3.27	1.29	-.29	-.96
ii3	3.18	1.26	-.26	-.97
Design Quality Goal Achievement				
dq1	4.19	.88	-.96	.33
dq2	4.24	.88	-1.17	1.27
dq3	4.07	.90	-.80	.22
dq4	4.15	.91	-1.12	1.03
dq5	4.05	.94	-.85	.26
dq6	4.20	.86	-.97	.45
Design Quality Goal Aggressiveness				
dqa1	3.34	1.34	-.40	-1.03
dqa2	2.98	1.33	-.07	-1.16
dqa3	3.11	1.30	-.15	-1.09
dqa4	3.24	1.36	-.27	-1.20
dqa5	3.02	1.23	-.20	-.96
dqa6	2.92	1.29	.07	-1.09
Design efficiency Goal Achievement				
pe1	3.68	1.20	-.63	-.56
pe2	3.41	1.21	-.30	-.84
pe3	3.40	1.25	-.38	-.85
pe4	3.42	1.30	-.43	-.94
Design efficiency Goal Achievement				
pe1	3.68	1.20	-.63	-.56
pe2	3.41	1.21	-.30	-.84
Task Relevant Expertise				
tre1	4.19	.92	-1.18	1.11
tre2	4.14	.92	-1.11	1.08
tre3	3.76	1.09	-.78	.14
tre4	3.91	1.08	-.92	.27
tre5	3.91	1.10	-1.02	.52