Involving Suppliers in New Product Development: Coordination Fit, Goal Congruence and Collaboration Quality

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Abstract. Original equipment manufacturers (buyers) are increasingly involving component suppliers in new product development as a means to be efficient and expand capabilities. To realize such benefits, however, both *incentives* and *actions* of the buyer and supplier need to be aligned. This study draws from Information Process Theory to propose that there is an optimal level of procedural coordination that maximizes design performance, i.e. higher task interdependency requires more procedural coordination. The positive effects of goal congruence on design performance are built upon team/group management literature and agency theory. Finally we use Hackman's theory of work group effectiveness to propose that collaboration quality, an *emerging* state, mediate the effects of coordination fit and goal congruence, two organizational d*esign* factors. Theoretical contributions, practical implications and future directions are discussed.

Keywords. new product development, supplier involvement, work group effectiveness, procedural coordination, goal congruence, collaboration quality

1. Introduction. More and more original equipment manufacturers (OEMs, referred to as buyers in the remaining text) are starting to involve their component suppliers (referred to as suppliers in the remaining text) in NPD projects. This practice is found to be one of the key differentiators between leaders and lagging companies in the midst of the recent economic crisis in the North America automobile industry (Harbour-Felax, 2009). Supplier involvement in product development has commonly been 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). 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. 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, both *incentives* and *actions* of the buyer and supplier need to be aligned. Goal congruence, the extent to which a buyer and a supplier perceive the possibility of common goal achievement, is an indicator of incentives alignment (Jap 1999). On one hand, both positive effects of goal congruence (Zeng and Chen 2003, et al.) and negative effects of goal conflicts (Park and Ungson 2001, et al.) have been identified by the literature. On the other hand, benefits associated with a mediate level of goal incongruence, in terms of maximizing problem solving capability, have also been found (Weick 1979, Thomsen 1998). In the context of buyer-supplier product design, Peterson et al. (2003) found that inter-firm agreements on key targets improve project team effectiveness. However, such firm-level agreements are not the same as group-level goal congruence. Thus it is still not clear whether goal congruence between two groups of people, one group representing one firm, is effective or counter-productive in improving project outcomes. This study attempts to fill this gap by examining effects of inter-firm goal congruence on project performance, mediated by collaboration process effectiveness.

Aligned actions are realized through procedural coordination, defined as the day-to-day exchange of information between employees from two firms (Doz, Hamel and Prahalad, 1989:136, Sobrero and Schrader 1998). Some studies found that frequent information sharing lowers transaction costs (Dyer 1997), enables inter-organizational collaboration (Chae et al. 2005), improves both buyers' and suppliers' performances (Cai et al. 2006, Sanders 2007, Peterson et al. 2003), increases project success rates (Baltontin et al. 1999), and improves design quality (Takeishi 2001, Jayaram 2008). Some other studies, however, 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. Not only differing in frequency, procedural coordination mechanisms also varies on richness of media, ranging from electronically mediated to face-to-face communication (Sobrero and Schrader 1998). Antioco et al.(2008) found that communication channels and information content affects the information use of product designers, which ultimately affect design performance. The literature, however, doest not tell us how procedural coordination should be properly structured, in terms of at the right frequency and using the right media, to maximize performance of a project involving a buyer and a supplier. This study, adopting the information processing theoretic perspective, proposes that coordination mechanisms should structurally fit the inter-firm task structure in order to be both effective and efficient.

In addition to be aligned in incentives and actions, the effectiveness of the collaboration process, or collaboration quality, is also a key factor in affecting group performance (Zeng and Chen 2003, Das and Teng 1998, Kahn 1996, Gomes et al. 2003, etc.). Three main indicators of a high quality collaborating process are: high quality communication, mutual supports and commitments ((Hackman 1987, Campion et al. 1993, Gray 1985, 1989, Wood and Gray 1991, Amabile et al. 2001, Jassawalla and Sashittal 1998, Tjosvold 1984, 1995). An effective collaboration process exhibits high values on all the three dimensions. Hoegl and Wagner (2005), for the first time, studied collaboration quality as a single construct measured by all the three indicators. They found that high collaboration quality improves NPD project outcomes, after controlling for the curvilinear effects of communication frequency and intensity. It is not clear, however, what factors contribute to the emergence of a high quality process when a buyer and a supplier collaborates on product design.

Although the literature implies the importance of inter-firm alignment in action and incentives as well as a high quality collaboration process, the discussion is generally scattered and disorganized. A systematic investigation of the relationship among inter-firm action and incentive alignment, collaboration quality and NPD project performance is lacking. We fill this gap by answering four research questions, in the context of buyer-supplier product design, adopting Hackman's work group effectiveness theory (Hackman 1987):

(1) Is more procedural coordination between a buyer group and a supplier group always better, or could procedural coordination be too much?
(2) What are the effects of inter-firm goal congruence on NPD project performance?
(3) What are the effects of inter-firm collaboration quality on NPD project performance?
(4) Does collaboration quality fully or partially mediate the effects of coordination fit and goal congruence on NPD project performance?

With this study we contribute to the literature by studying the causal relationships between inter-organizational *design* factors and *emerging* process characteristics. Specifically we proposed that over-coordination, a situation where the coordination mechanisms provides more than necessary information processing capacity, lowers project process efficiency without improving design quality. Adopting a dyadic perspective, we propose that the *match* between two firms in both actions and incentives is an important project success factor. Specifically, the match in both activities and incentives helps building a high quality collaboration process. Finally we extend Hackman's work group effectiveness theory to an inter-organizational product design context for the first time.

2 Research Context and Scope.

2.1 Problem Context and Unit of Analysis. The research questions are studied in a context where OEMs, as buyers, involve their suppliers into the detailed design phase of NPD projects. According to Ulrich (1995)'s four-stage model for NPD projects, the detailed engineering phase is after the concept development and system-level design and before product text and refinement This stage is mainly concerned with the process of developing a fully defined product design from a clear set of requirements while creating deliverables and documentation appropriate for product manufacturing.

The unit of analysis is a buyer group-supplier group (BG-SG) dyad, in the context of a project to complete a component's detailed design (Figure 2-1). Each dyad is composed by two groups of people, one group from one 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 component. It is, however, always responsible for making sure that the component design fits into the whole product and is manufacturable. The supplier group is always actively involved in the core design job for a component. Production for the component could be either done internally by the buying firm, or outsourced to the same supplying firm who is involved in design, or to a third-party contractor.

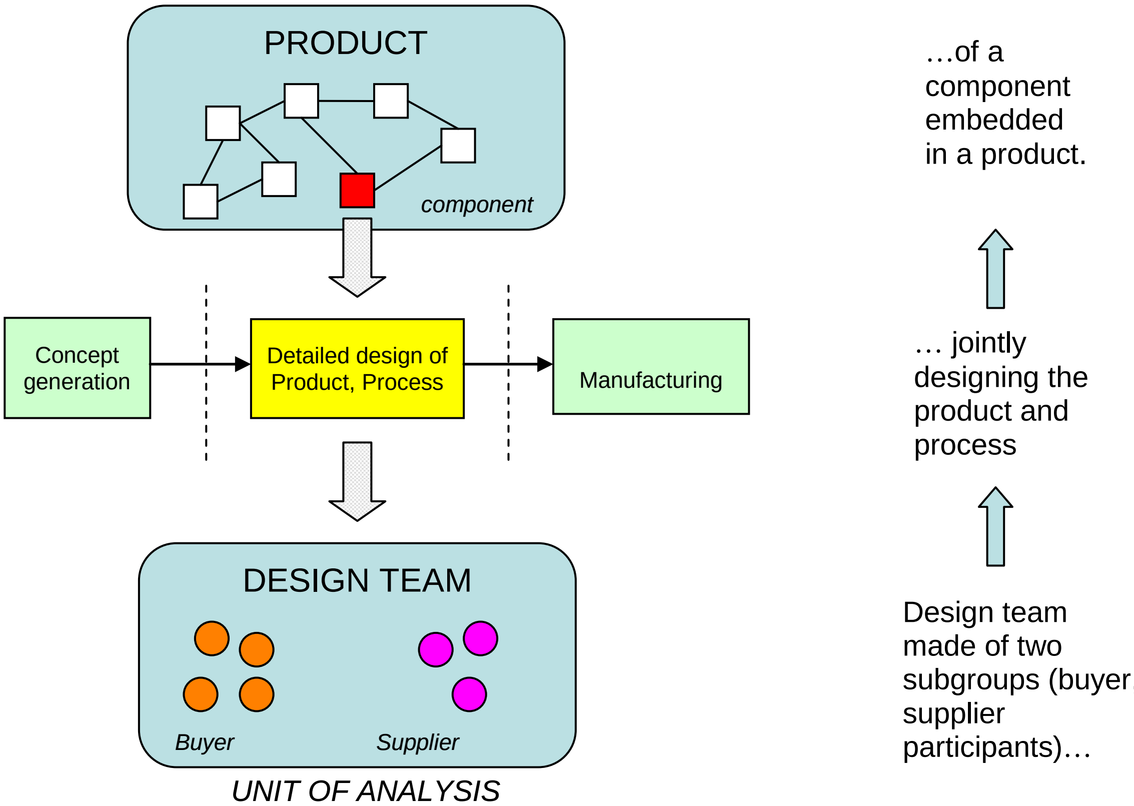

Figure 2-1 Problem context and scope

2.2 Component, Work Group, Task Interdependency and Design Performance. In this study a component is defined as a product unit of which a single supplier is involved in the majority of value-added activity in the design process. Thus one component only involves one buyer-supplier dyad, as one work group. 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 the door, instead of being one single component, is treated as two components, each of which involves only one supplier. Thus each component suggests one 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.

In the detailed engineering phase of a NPD project, a work group is composed by engineers and other professionals from both firms, designing the same component. According to Hackman and Wageman (2005)'s definition, this set of people can be distinguished reliably from other people in the project due to their common task. 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: the whole project. What is unique about a work group studied in this study 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 component design that (1) fits into the overall product architecture, (2) fits with target customers' requirements, (3) is manufacturable, (4) consumes the least amount of time and cost in the design process. Three sources of task interdependency are discussed below.

First, the two sub-groups are interdependent due to the dependency 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 group, acting as the system integrator, is always responsible for integrating individual component designs into the overall product architecture (Parker and Anderson 2002). Supplier groups are responsible for a part or all of the detailed design work for individual components. Thus the two sub-groups are interdependent on each other for delivering a design that does not interfere with other interrelated component designs in the final product.

Second, the two sub-groups are interdependent due to the way the component design task is decomposed between them. When two sub-systems of the focal component 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.

Third, design-manufacturing interdependency may cause tasks of the two sub-groups to be interdependent. 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 "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.

We consider two types of design performance. The first one is component design quality, which measures the degree to which the component 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 fits target customers' needs. The second one focuses 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 two dimensions of process efficiency are: development cost and time.

3 Theoretical Bases and Hypotheses.

3.1 Coordination Fit: Choosing the Right Level of Procedural Coordination.

3.1.1 Theoretical Basis. The propositions regarding the fit between procedural coordination and task interdependency are built upon Information Processing Theory, which has its roots in organizational design and coordination literature.

The organizational design literature has been proposing the alignment between organizational structure and task environments for a long time (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 right organizations should be designed to both reduce task uncertainty and resolve task equivocality.

In addition to formal organizational structure, informal coordination mechanisms, such as unplanned face-to-face contacts between members from different teams, could 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 (Haag, 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 structures with task environments. 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 task interdependency across organizational boundaries. In the next section, two types of coordination: contractual and procedural, used in structuring inter-organizational relationships are discussed. Then based on IPT, the fit between procedural coordination and inter-organizational task interdependency in the context of NPD is proposed to improve project outcomes.

3.1.2 Procedural Coordination and Task Interdependency. According to Sobrero and Schrader (1998), “two fundamental dimensions which characterize the structuring of inter-firm relations: contractual coordination and procedural coordination.” (pp. 585). Contractual coordination refers to the mutual exchange of rights between the two firms (Sobrero and Schrader 1998). The contract seeks to align incentives and interests between both firms, and represents ex ante promises or obligations to perform particular actions in the future (Poppo and Zenger 2002). Contractual coordination, however, is not sufficient to achieve coordinated activities among members from the two firms since autonomous parties read and react to signals differently even if their incentives are well aligned (Williamson 1991). Procedural coordination relates to the “mutual exchange of information for the combination of agents or functions towards the production of results” (Sobrero and Schrader 1998, pp. 587).

In our problem context, contractual coordination is done at the top-management of the two firms. It does not tell us how members in the two sub-groups coordinate their engineering activities through exchanging technical information. Procedural coordination in a BG-SG dyad in a NPD project refers to the information exchange norms and processes that promote a shared understanding of the task environment and mutual adjustment in design activities. It is important to solve coordination problems arising due to the cognitive limitations of individuals that prevent them from knowing how others will behave in situations of interdependence, and how they are interdependent with others” (Gulati 2005). Thus in this study, we will only focus on procedural coordination.

Procedural coordination differs on frequency, timing, media and directionality (Sobrero and Schrader 1998, Sobrero and Roberts 2002). Except timing, all the other three dimensions are related with information processing capacity of procedural coordination. When the two groups mutually exchange information more frequently through richer media, on one hand, they are able to process more information in a given amount of time; on the other hand, they need to spend much more resources, such as time, in coordination. Too much coordination, a major type of group process loss, diverts engineers’ efforts from core design work, which lowers work productivity and process efficiency (Hackman 1987).

From the IPT perspective, therefore, the level of procedural coordination should fit with the level of task interdependency between the two sub-groups to deliver the best design in a most efficient way. According to the three sources of task interdependency mentioned at the end of section 2.2, the two sub-groups should engage in a higher level of procedural coordination: (1) when a supplier is engaged in developing a component that shares strong interface with other components in the system, and/or (2) when the design task for the focal component is partitioned in a way that tasks of the two sub-group are highly interdependent, and/or (3) when the manufacturing process is sensitive to changes in design and no one sub-group has full access to both design and manufacturing information.

3.1.3 Performance Implications of Under- and Over-coordination. There are two types of misfit between procedural coordination and BG-SG task interdependency: under- and over-coordination. When procedural coordination provides too much (less) information processing capacity, the group task is over- (under-) coordinated.

The two types of misfits have different effects on component design quality. Only under-coordination (the coordination mechanism is too mechanistic) will be negatively associated with component design quality. Lack of timely information is the cost of under-coordination. When task is under-coordinated, engineers could not obtain design interference information and adapt to interferences by making design changes in a timely fashion. Thus under-coordination increases the chance that the design does not fit with either other components, or with customers' needs, or with the manufacturing process. Under-coordination between the two firms may also reduce design functionality and durability due to a lack of alignment in interdependent design activities within the BG-SG dyad for designing the component. Over-coordination does not affect design quality because the enough information processing capacity is provided to manage task interdependency. Thus we propose that:

Hypothesis 1a: Under-coordination is negatively associated with component design quality.
Hypothesis 1b: Over-coordination is not significantly associated with component design quality.

Both under- and over-coordination are negatively associated with process efficiency. Due to a lack of timely information sharing and effective decision making in early stages of the design process, under-coordination increases the chance that the design has to be modified in later stages, which is more costly and time-consuming. An example of negative effects of under-coordination on development time 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 coordination 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. The cost of over-coordination is a waste of resources on unnecessary coordination, 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. Thus choosing the optimum level of coordination always improves process efficiency. Thus We propose that

Hypothesis 1c: Coordination fit leads to higher process efficiency.

3.2. Goal Congruence.

3.2.1 Theoretical Basis. Goals are concerned with desired future states of the world, and represent the underlying motives for intentional behavior (Mintzberg, 1983). Present actions could be characterized and attitudes toward future conduct could 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 incongruence could be caused by different preferences in ranking multiple goals. Autonomous units often prioritize goals differently, due to their local expertise and social embeddedness in institutional infrastructure of their respective “communities”. A typical example is the conflicts 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 at all costs and procurement wants to minimize costs. Such goal incongruence 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).

Goal incongruence may also be caused by autonomous units’ self-serving orientation (Eisenhardt 1989). The classical agency problem is an example of goal incongruence between 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 incongruence could be identified in a lot of relationships, such as employer-employee, lawer-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).

No matter what cause it, goal incongruence 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, 1985, 1989; Levinthal, 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). Goal congruence in international product development teams enhances expectation and improves communication (Moenaert et al. 2000). Shared priorities enhance the single-minded direction that the project team is moving toward (Witt et al., 2001). The congruence between an individual's and a team's goals is shown to be crucial for team performance (Kristof-Brown and Stevens, 2001). Gowen (1986) found that such individual-team goal congruence can increase productivity by 31%.

In an inter-organizational setting, goal congruence is defined as “the extent to which firms perceive the possibility of common goal accomplishment” (Eliashberg and Michie, 1984), and is used for estimating the degree of incentive alignment among supply chain entities. Buyer-supplier goal congruence facilitates coordination efforts and idiosyncratic investments by both parties in the dyad (Jap 1999). In a following study, Jap and Anderson (2003) found that, at higher levels of opportunism, buyer-supplier goal congruence acts as a more powerful safeguard, compared with interpersonal trust, in preserving exchange outcomes and expectations of relational continuity. A lack of congruent goals increases inter-organizational “friction”, which lowers effectiveness and efficiency of their interactions. Tabrizi and Walleigh (1997), for instance, argue that buyer-supplier differences in style, priorities, and motivation increase costs of projects with supplier involvement. Buyer-supplier task interdependency further amplifies the negative effects of goal incongruence on inter-organizational coordination costs (Lakemond et al. 2006). In a recent study of buyer-supplier relationships, Rossetti and Choi (2008) shows that inter-firm goal incongruence leads to supply chain disintermediation, the risk of a supplier entering its buyer’s aftermarket. In a principal-agent relationship, goal incongruence also increases monitoring costs for the principal. For instance, Sapienza and Gupta (1994) found that goal incongruence between venture capitalist (VC) and CEO of new ventures will lead to higher monitoring cost, in terms of more VC-CEO interactions, for the VC.

However, goal incongruence is not always bad. New data from experiments in social psychology indicate that an intermediate level of goal incongruence may have potentially positive effects on group problem-solving performance (Amason, 1996; Jehn, 1995; Pelled, 1996; Watson et al., 1993). Goal incongurency, 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, goal incongruence 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). Similar findings could be identified in organizational demography research. For instance, group heterogeneity could improve solution creativity through increasing diversity and requisite variety (Hoffman and Maier 1961, Morrison 1992, Weick, 1979). Furthermore, groups are more effective at solving complex, non-routine problems when they are composed of individuals with different perspectives (Shaw, 1976; Wanous and Youtz, 1986). In sum, diversity in cognitions and views can prevent “group thinking” and motivate group members to search for better solutions.

3.2.2 Goal Incongruence in a BA-SG Dyad. In a BG-SG dyad, both types of causes could lead to varying goals across the two groups. First, the two groups may prioritize multiple goals differently. We call this Type 1 goal incongruence. For instance, the buyer group may want a design that best satisfies its customers’ functional requirements, while the supplier group may just want a design that could be produced in a fast and cheap way. Second, different goals held by the two groups may simply be caused by each firm’s opportunistic behaviors driven by self-serving orientation. We call this Type 2 goal incongurency. If the two firms do not expect a long term relationship, agency problems may occur on the group level. For instance, if the supplier firm finds itself too exposed to technology diffusion risk, it may tell the supplier group not to share key technology information with the buyer group. Under this circumstance, although both groups may target improving design functionality, the supplier group has one more goal: preventing key technology information from being disclosed to the buyer, which is not congruent with shared goals of the two groups. A possible outcome of such goal incongruence is double-marginalization, a typical problem in decentralized system where local agents’ self-serving behaviors cause the failure to reach global optimum (Spengler 1950).

Based on the literature reviewed in section 3.1.1, the two types of goal incongurency seem to have different effects on performance of a BG-SG dyad. A medium level of Type 1 goal incongurency, an indicator of diversity in opinions, perspectives and knowledge, is beneficial for the BG-SG dyad in terms of forcing both sub-groups to search for a better solution. Type 2 goal incongruence, an indicator of agency problems, is always detrimental to group performance. Therefore it seems not clear whether the total amount of goal incongruence is good or bad for delivering a good design.

In the detailed design phase of a NPD project, we propose that both types of goal incongruence lower project performance. When two groups of people prioritize goals differently (Type 1), their corresponding actions will be in conflict with each other. For instance, one group focusing on innovation may spend a lot of resources in explorative trials, while the other group targeting efficiency may prefer to spend the same amount of resources in exploiting existing technology and knowledge. With Type 1 goal incongruence, both groups have to spend more time negotiating with each other to reach an agreement, which takes away engineering hours from the core design work. Literature has shown that buyer-supplier agreements on technical and business goals are positively associated with NPD project team performance (Peterson et al. 2005). When the buyer and supplier groups agree on the expected benefits associated with the supplier integration efforts, in terms of quality, cost, scheduling, the outcome is not only a new product, but often lower costs as well (Laseter and Ramdas 2002, Ragatz et al. 2002). Thus Type 1 goal incongruence is unproductive. Because Type 2 goal incongruence is always detrimental for inter-organizational collaboration (Eisenhardt 1989, Jap 1999), the total effect of both types of goal incongruence on project performance should be negative.

Both component design quality and process 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; both groups are 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 process efficiency through improving productivity. Thus we propose that:

Hypothesis 2a: Goal congruence leads to higher component design quality.
Hypothesis 2b: Goal congruence leads to higher process efficiency.

3.3 Collaboration Quality.

3.3.1 Collaboration Quality and Design Performance. Propositions regarding effects of collaboration quality on design performance as well as its mediation roles are built on Hackman's theory of group effectiveness (Hackman 1987). As defined in section 2.2, a work group is a BG-SG dyad who works on the detailed design of one component in the final product. BG-SG collaboration quality measures the extent to which the two sub-groups mutually support each other, engage in high-quality communication and are fully committed to the project, the three dimensions of an effective collaboration process.

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 (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 mentioned 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.

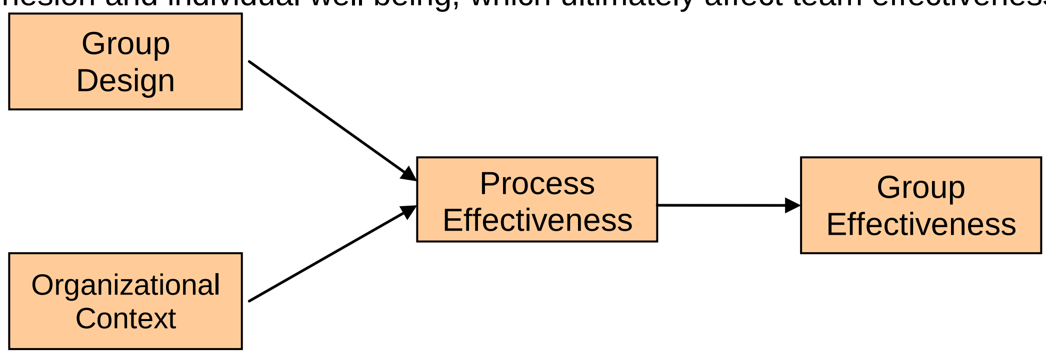

Figure 3-1: Hackman's theory of group effectiveness (adapted from Hackman 1987)

From the perspective of work 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 and high commitment to the projects (Hoegl and Gemunden 2001, Hoegl and Wagner 2005). These characteristics are all associated with higher design quality and process efficiency. To achieve high component design quality, frequent design changes are necessary to solve interferences. If the buyer and supplier members are not willing to adapt to and fully support such design changes, design quality will be compromised. If important ideas are shared openly, high-quality information is made available in a timely fashion, and all the group members are fully committed to the design task, shorter development time and lower development cost could be achieved.

Building upon the above logic, we propose that:

Hypothesis 3a: Collaboration quality is positively associated with component design quality.
Hypothesis 3b: Collaboration quality is positively associated with process efficiency.

3.3.2 Collaboration Quality as a Mediator. According to Hackman's model, collaboration quality serves as a mediator transferring effects of group design and organizational context on group performance. Group design factors include the structure of the group task, the composition of the group, and group norms that regulate member behavior. Organization 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. The two independent variables: coordination fit and goal congruence, are such organizational context factors, whose effects are mediated through collaboration quality.

Coordination fit 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, one criteria of process effectiveness (Hackman 1987). Similarly, when a buyer group and a supplier group, working on interdependent tasks, exchange the optimum amount of information to coordinate their activities, their collaboration process becomes more effective.

Both over- and under-coordination reduces collaboration quality in its three dimensions. When over-coordinated, group members' time and energy are diverted to unproductive coordination activities, thus reducing sufficiency of efforts applied to core design activities (commitment). Being tied up with unproductive coordinating activities reduces capability to well adapt and support others' needs (mutual supports). Finally important ideas are more likely to be ignored by receivers due to information overload, leading to lower information timeliness and accuracy (communication quality). When under-coordinated, interferences among interrelated engineering activities cause more re-work, thus reducing sufficiency of effort spent on productive activities (commitment). A lack of information on what the other group is doing reduces the capability of mutually supporting each other (mutual supports).. Finally information timeliness and accuracy are reduced due to a lack of relevant information (communication quality).

Thus we propose that:

Hypothesis 4: Coordination fit 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 in its three dimensions. 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 (commitment). If the two groups have congruent goals, they are more likely to mutually support each other to adapt to changes (mutual support). Congruent goals held by the two groups also motivate them to share high quality information in a timely fashion (communication quality).

Thus we propose that:

Hypothesis 5: Goal congruence is positively associated with collaboration quality.

Figure 3-2 shows the conceptual model

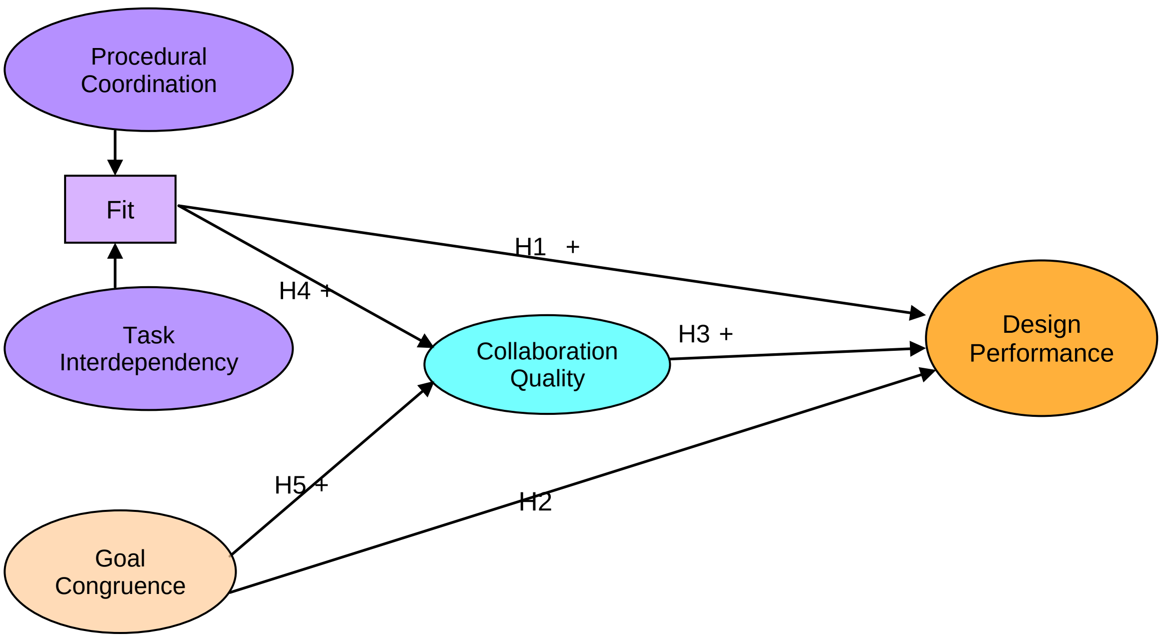

Figure 3-2: the conceptual model

4 Discussions.

4.1 Theoretical Contributions. Theoretically, this study proposed the concept of over-coordination, a situation where the coordination mechanisms provides more than necessary information processing capacity. Specifically, it is proposed that over-coordination lowers project process efficiency without improving design quality. Literature studying supplier involvement in NPD often focuses only on benefits associated with inter-firm procedural coordination. More coordination 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 process efficiency (Ragatz et al. 2002, Sobrero and Roberts 2002, Jayaram 2008). The costs of coordination, 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 coordination have not received enough attention. Adopting a contingency perspective, this study proposes that coordination is not always needed. When tasks between the two firms are decomposed in a way that task interdependency is low, too much coordination just distracts engineers' efforts to unproductive activities.

This study treats a BG-SG dyad as the unit of analysis, emphasizing the match between the two groups, each representing a different firm. The literature often uses characteristics of individual firms or technical/environmental factors to predict performance of NPD with supplier involvement. For instance, Peterson et al. (2003) emphasizes the importance of choosing the right supplier, through assessment, in building an effective project team. Buying firms' internal integration (Takeishi 2001, Koufteros et al., 2005) is also found to be an important success factor for supplier involvement in NPD projects. Technical difficulty (Primo and Amundson, 2002), technical uncertainty (Ragatz et al., 2002) and market stability (Jayaram, 2008) have also been found to affect project performance, when suppliers are involved. The nature of the buyer-supplier dyad, however, is largely ignored. Few studies that did study it focus only on inter-firm trust and commitment (Walter 2003, Barbara Flynn 2000, Song and Benedetto 2008), ignoring the match between the two firms. Thus this study contributes to the literature by proposing that the match between the buyer group and the supplier group in actions and incentives are important success factors for supplier involvement in NPD.

Third, causal relationships between *ex ante* design factors and *ex post* emerging process characteristics are studied for the first time. Ex ante design decisions made before the design process begins, such as timing of involvement, design responsibility, communication frequency, and suppliers' membership on design teams, have been widely studied (Ragatz et al. 1997, Handfield et al. 1999, Monczka et al. 2000, Peterson et al. 2005, Koufteros et al. 2007). What actually happens during the design process, or the emerging ex post nature of the collaboration process, has not received enough attention. This study contributes to the literature by not only examining effects of the emerging process nature, but also proposing a causal relationship between what are designed ex ante and what emerges ex post.

4.2 Practical Implications. Practically, this study suggests that it is not appropriate to coordinate with all the involved suppliers in the same way. Depending on how design task and design/manufacturing information is decomposed between the two firms, different dyads may have different levels of task interdependence. For dyads with higher task interdependence, more frequent information exchange using richer media is necessary.

Then buyers are reminded of costs associated with over-coordination. 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 misaligned activities or aligning activities inefficiently. Furthermore, over-coordination is proposed to prevent an effective collaboration process from emerging, which ultimately lowers design performance. Thus it is possible that the more a buyer communicates with a supplier, the less supportive the supplier becomes due to the overwhelming unproductive information sharing activities.

This study identifies three sources of inter-firm task interdependency, which offer a more complete view on inter-firm interdependency in the design process. An important message is, even when the component design task is decomposed into two completely independent modules, each designed by one firm, the two firms may still be highly dependent on each other. For instance, the supplier is always dependent on the buyer for information of either product architecture or customer requirements. The buyer may be dependent on the supplier for manufacturability constraints and capability. Thus modular task decomposition can not remove all the interdependencies. Recognizing all the three sources could help buyers to purposely reduce interdependency, thus increasing process efficiency (Sobrero and Roberts 2002). For instance, buyers could involve suppliers whom they have worked before to reduce the need for explicit coordination due to existence of shared cognition and values, which is a form of implicit coordination (Espinosa et al. 2002, Espinosa and Pickering 2006).

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. This proposition, if empirically verified, could lend supports for Peterson et al. (2003), which found that inter-firm agreements on business and technical targets are positively associated with project team effectiveness. If the two firms do not agree on key targets, friction costs generated by such incongruence will outweigh benefits of diversity in perspectives, thus worsening project performance.

Finally it is important to monitor the on-going collaboration process. Even if the two firms coordinate 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 adapt to each other, or that they do not apply enough efforts to the core design task. Monitoring the daily inter-firm interaction may prevent a low quality process from emerging by adapting to early signs of low communication quality, little mutual supports and low commitment.

4.3 Future Directions. Further studies could be done to examine implications of inter-organizational relationships for group-level interactions in collaborative NPD projects. The level of analysis in this study is a BG-SG dyad. Thus characteristics of the buyer-supplier relationships on a firm-firm level are not directly captured in our model. Characteristics of inter-organizational relationships, however, are widely believed to affect how people from the two firms work together (Heide and Miner 1992, Sobrero and Schrader 1998, Heimeriks and Duysters 2007, 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 operational and relational factors' effects. Significant cross-level effects, if identified, could show the importance of strategically building and maintaining good relationships with suppliers long before they are involved in any projects for successful project-level involvement.

Effects of the two types of inter-organizational goal congruence on project performances could be further studied. In this study, the two types of goal congruence are subsumed under one single construct. However, both types independently exist in reality and may affect project outcomes in different ways. 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) whether a certain level of Type 1 goal incongruence should be maintained, (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, performance of the productive output is the only criterion used to evaluate the effectiveness of a 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 the future, in terms of improving cooperative competency. However, longitudinal data is needed to do such researches.

Different types of inter-firm task interdependence also deserve more studies in the future. In this study, we identified three sources of task interdependence. However, all the three types are measured under one single construct: task interdependence. And it is assumed that all these interdependencies, either sequential or reciprocal, are coordinated using the same mechanisms. Researches have shown that different types of interdependencies should be coordinated in different ways (Haag, 2006). Thus it is important to examine whether coordination mechanisms should fit not only with the level, but also with the type of task interdependency, in delivering the best outcomes.

Finally effects of action and incentive alignment on innovation performance could be further studied. In this study, we only focus on design quality and process 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 product and process innovation are outcomes that are evaluated.

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