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## Information sharing in a new product development project: The role of core actors

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**Information Sharing in a New Product Development Project  
- The Role of Core Actors**

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## Abstract

The success of NPD projects of high-cost, engineering-intensive, and customized development products is largely dependent on information sharing with actors from customers regarding their specific requirements (Von Hippel, 1986). But information sharing is also necessary among actors from different departments within the organisation (Song and Swink, 2009) regarding such topics as available technical options. Project managers (PMs) are at the heart of this process and plays an essential role in orchestrating the information sharing among various intra-organisational actors (e.g. among actors within the NPD organisation) and inter-organisational actors (across organisational borders, among actors for example from a department within the NPD organisation and a supplier) (Clark and Fujimoto, 1991). Consequently, the PM ensures that varied expertise and critical information are integrated in a timely fashion into the development process (Edmondson and Nembhard, 2009). However, prior research has not simultaneously studied and addressed the differences in intra- and inter-organisational information sharing during the various phases of the NPD project (Kivimaki and Lansisalmi, 2000). Furthermore, relative to intra- or inter-organisational information sharing, comparatively less research has been conducted to investigate the role of the project manager (PM) in orchestrating the information sharing among various intra- and inter-organisational actors (Clark and Fujimoto, 1991). Research has shown that heavily burdened PMs require assistance in the information sharing process not only from project team members (Sarin & O'connor, 2009) but also from other intra-organisational actors e.g. from a specific department within the NPD organisation (Clark & Fujimoto, 1991). However, research on so-called core intra-organisational actors' relationships with whom the PM establishes relationships with during the NPD phases remains quite limited, and to my knowledge, no other research has studied the role of the inter-organisational actors from this perspective.

Therefore, aim of this paper is to provide additional theoretical insights into how the PM through relationships with core actors orchestrates information sharing among other intra- or inter-organisational actors during the progression

of an NPD project. In other words, this study emphasises the importance of the PM's relationships on a day-to-day basis in information sharing among intra- and inter-organisational actors during the phases of an NPD project.

This study is an analysis of longitudinal objective email data, and is based on the email exchange (consisting of 4658 emails) to and from intra-organisational actors during the progression of a large NPD project lasting more than two years. The email data were analysed using UCINET software (Borgatti et al., 2002). Normally, such data regarding development projects are quite difficult to access because such projects extend over long periods of time and involve highly complex and sensitive information. Thus, by building on email data that represent the activities that have actually occurred, this paper contributes to the existing literature by exploring the day-to-day practices of both the PM and other core actors during a NPD project.

The main conclusion of the study is that the information sharing process during an NPD project is a complex, dynamic process, involving a large number of actors (in this case 373 actors) of diverse functions from different organisations. The results reveal changes in both the structure and intensity of information sharing with intra- and inter-organisational actors. Significant changes in the structure of simultaneous intra- and inter-organisational information sharing are detected when comparing the two early NPD phases with the two later phases. The intensity in information sharing is found to increase during the last two NPD phases. Further, the findings show that to orchestrate the information sharing during the NPD project, the PM relies on relationships with several core intra-organisational actors who are particularly important to the orchestrating of information sharing during the early phases of the NPD project. Unexpectedly, the study found that the PM also receives assistance from core inter-organisational actors from the customer company when orchestrating the intra- and inter-organisational information sharing, especially during the later phases of the NPD project. The findings contribute to the understanding of the different types of relationships by which the PM orchestrates information sharing among actors within and outside of the organisation on a day-to-day basis. The

findings indicate that support from both intra- and inter-organisational core actors is crucial to NPD project managers. Additionally, the results regarding the importance of various core actors across the life cycle of the NPD project can be used to identify relationship requirements when planning stakeholder management activities across the phases of a project.

**Keywords:** Intra- and Inter-organisational information sharing, internal and external core actors, project management, new product development, project phases, in-depth case study with objective data.



## **Table of Contents**

1. Introduction .....	9
2. Conceptual framework .....	11
3. The structure in intra- and inter-organisational actors’ information sharing .....	12
4. The intensity in information sharing of intra- and inter- organisational actors .....	14
5. The Project Manager and Core Actors .....	15
6. The PM’s relationships during the phases of NPD projects .....	18
7. Empirical Setting and Data Collection .....	22
8. Method of Analysis .....	28
9. Results .....	29
10. Discussion .....	49
11. Conclusions and Limitations .....	57
12. References .....	61
13. Appendix A: Networks Pictures Regarding Essay III .....	66





# 1. Introduction

This paper studies the structure and intensity of intra- and inter-organisational information sharing during the phases of an NPD project; however, the primary focus is on the PM's relationships with so-called core actors<sup>1</sup> when orchestrating information sharing among other intra- or inter-organisational actors during the progression of an NPD project.

The success of NPD projects of high-cost, engineering-intensive, and customized development products is largely dependent on information sharing with actors from customers regarding their specific requirements (Von Hippel, 1986). Furthermore, information sharing is necessary among actors from different departments within the organisation regarding such topics as available technical options (Song & Swink, 2009). Although research has found that both the structure and the intensity in the network are important components of information sharing in NPD projects (Hoegl & Weinkauff, 2005; Sarin & O'connor, 2009; Tortoriello, Reagans, & McEvily, 2012), prior research studies have not simultaneously studied and addressed the differences in intra-organisational information sharing (among actors within the NPD organisation) and inter-organisational information sharing (across organisational borders, among actors for example from a department within the NPD organisation and a supplier) during the various phases of the NPD project (Kivimaki & Lansisalmi, 2000).

The ability of NPD project actors to share information with other intra- and inter-organisational actors has been found to be essential for NPD projects (Kratzer, 2001), and PMs are at the heart of this process because they orchestrate the information sharing among various intra- and inter-organisational actors (Clark & Fujimoto, 1991).

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<sup>1</sup> The term *actor* is used for individuals, departments, or organisations. In this paper, *actors* are project participants who are directly involved in the project information sharing during the NPD project lifecycle.

The PM of an NPD project plays an essential role in structuring and facilitating the information-sharing process between team members and the rest of the organisation but also between actors from the developing company and external actors, such as suppliers and customers during the NPD process (Clark & Fujimoto, 1991). Consequently, the PM ensures that varied expertise and critical information are integrated in a timely fashion into the development process (Edmondson & Nembhard, 2009).

Research has shown that heavily burdened PMs require assistance in the information sharing process not only from project team members (Sarin & O'connor, 2009) but also from other intra-organisational actors e.g. from a specific department within the NPD organisation (Clark & Fujimoto, 1991). However, research on core intra-organisational actors' relationships with whomever the PM establishes relationships with during the NPD phases remains quite limited, and to my knowledge, no other research has studied the role of the inter-organisational actors from this perspective.

In sum, past research has not specifically addressed the following issues: the changes in the structure and intensity of intra- and inter-organisational actors' information sharing during the phases of an NPD project, or even more interesting the role of the relationships with core actors through which the PM orchestrates the information sharing.

First, on an overall level, I will investigate the structure and intensity of intra- and inter-organisational information sharing during an NPD project. This study will therefore address the following overall research questions:

- *R1: How does the structure in intra- and inter-organisational information sharing change during the phases of an NPD project?*
- *R2: How does the intensity in intra- and inter-organisational information sharing change during the phases of an NPD project?*

Then, more in-depth, I will identify the core actors of the NPD project during its different phases, and, finally, I will examine with which of these specific core actors the PM establishes relationships. Therefore, the most central research question to be addressed in this study is as follows:

- *R3: Which core actors support the PM in orchestrating information sharing at which specific phases during the NPD project?*

In general, research never explores the day-to-day practices of the intra- and inter-organisational activities of PMs and other core actors during NPD projects. The data regarding development projects are quite difficult to access because such projects extend over long periods of time and involve highly complex and sensitive information. However, by utilising this important dataset and attempting to fill important gaps in the existing literature, a better understanding of a PM's relationships with core actors might improve stakeholder management activities and information sharing in NPD projects.

## **2. Conceptual framework**

Research has found that information sharing among different individual actors of NPD projects is essential to the success of NPD projects (Clark & Wheelwright, 1992; Knudsen, 2007; Sarin & O'connor, 2009). Because actors render their individual knowledge accessible to other actors in an NPD project (Souder & Moenaert, 1992) by information sharing, new knowledge is created (Boisot, 1995) to develop new products (Song & Dyer, 1995).

Most research focuses either on intra-organisational information sharing among project team members (Ancona & Caldwell, 1992a), at an aggregated level between project teams (Hoegl et al., 2005) or departments within the organisation (Clark & Fujimoto, 1991; Song & Swink, 2009). Or on inter-organisational information sharing between the developer company and the suppliers (Knudsen,

2007) or the customers (Lettl, Herstatt, & Gemuenden, 2006; Von Hippel, 1986). However, there have only been a few attempts to investigate intra- and inter-organisational information sharing during an NPD project (Jepsen & Dietrich, 2012; Jepsen, Jepsen, & Dietrich, 2012). Jepsen and Dietrich (2012) focus on intra- and inter-organisational information sharing and the role of technology uncertainty whereas Jepsen et al. (2012) investigate the project manager's brokerage of information sharing between actors inside and outside of the developer company.

Every group (e.g. project team), function (e.g., sales, construction, and production department) or organisation (e.g. supplier, customer) is represented by individual actors. Each of these actors has different skills, information and experience that can be viewed as a pool of diverse information that requires sorting and sharing to garner sufficient knowledge for the NPD project (Souder & Moenaert, 1992).

Therefore, the sharing of information for NPD projects can be effectively explained by taking into account the intensity and structures of communication among individual actors (Cross & Parker, 2004; De Luca & Atuahene-Gima, 2007).

### **3. The structure in intra- and inter-organisational actors' information sharing**

In this paper, the information sharing structure refers to the configuration or system of relationships among actors in the NPD project network in which actors and actions are perceived as interdependent rather than independent (Wasserman & Faust, 1994). Network structures are developed from combinations of "dyadic" relationships between two actors, and the relational ties among actors allow the sharing of information (Wasserman & Faust, 1994). Thus, the structure of relations represents the logistics by which information is

shared (Henttonen & Kaisa, 2010). Previous research considering network structure and information sharing (applying social network analysis) in the field of NPD has typically focused on intra-organisational relations (Kratzer, Gemunden, & Lettl, 2008; Leenders, van Engelen, & Kratzer, 2003; Reagans & McEvily, 2003). Only a few studies partially consider inter-organisational relations (Hansen, 1999; Reagans & McEvily, 2003). Henttonen (2010) argues that in general the social studies should take context more into account and suggests that future research should consider the effect of team-external relationships – not only on the intra-organisational level but also on the inter-organisational level. A better understanding of the structure of the NPD network can enable managers to understand the interfacing of actors (Cross & Parker, 2004).

Project phases have different requirements and hence different information sharing needs, which must be orchestrated accordingly for the project team and NPD project to perform well. Researchers argue that there are four NPD phases: concept development, solution development, testing, and delivery (Gray & Larson, 2007). In the concept phase, the project is initiated, goals are set and agreements are made. Thus, information regarding specifications and requirements is required. In the solution and testing phases, the actual job is performed, and technical issues are tested and solved. Information regarding prior experience and results is required. Finally, in the delivery phase, the project is delivered and implemented. This phase necessitates information regarding practical issues. As Tushman (1978, p. 627) states, “As the work of a high performing project varies, its communication patterns will evolve to adjust to the new information requirements”. In other words, the information sharing structures of individual actors are not stable, but change during a project’s life (Tushman, 1978). Researchers have considered this phenomenon in an intra-organisational setting (Edmondson, 2003; Hoegl, Weinkauff, & Gemunden, 2004). Furthermore, because external contacts are required to gain access to a variety of information during the progression of an NPD project (Knudsen, 2007), there may also be different configurations of inter-organisational relationships during the NPD phases. However, it was not possible to identify studies on structural

relations with inter-organisational actors. In practice, these inter-organisational relationships exist and are part of the NPD project through relationships with intra-organisational actors. Previous research has found that inter-organisational relationships through the project manager's brokerage are linked to the intra-organisational relationships during the progression of the NPD project (Jepsen et al., 2012). However, no studies have researched the structural differences (focusing on the significant changes) in intra- and inter-organisational structural relations during the different NPD phases.

#### **4. The intensity in information sharing of intra- and inter-organisational actors**

Studies that have examined the intra-organisational structure in teams have often used the intensity (or density) in the network as an important structural property (Burt, 1992). The intensity in information sharing refers to the degree to which participants within a network are tied to one another. There seem to be opposing views on the benefits of network density. One view advocates that a low-intensity network provides the benefits of autonomy, freedom of action (Burt, 1997) and a lack of social pressure to conform, which improves creativity (Sarin & O'connor, 2009). On the other side, researchers argue that high intensity in information sharing creates successful team and NPD project performance (Allan, 1977) because high density is associated with more accurate and more reliable information (Ibarra, 1995). When an actor is surrounded by a densely connected network, other actors in that network have both direct and indirect information (through common third parties) on the needs of the focal actors, reducing information asymmetries among actors regarding complex activities such as product development (Ahuja & Lampert, 2001; Obstfeld, 2005). Network density also promotes trust and reciprocity among actors because they share these common third-party actors. Furthermore, dense networks allow actors to learn about other actors through common third parties and increase their "knowledge-based trust" and their willingness to help one another in the net-

work (Sosa, 2007). An actor embedded in a densely connected communication network should find it easier to share accurate and reliable information about product development with other actors.

Regarding the density of information sharing during the NPD phases, the results of network studies regarding autonomy, freedom of action (Burt, 1997) and creativity (Sarin & O'connor, 2009) strongly indicate that low density is beneficial to the idea and concept-generation phase in the NPD project. However, NPD literature argues for a dense network during the development and delivery phases to refine and coordinate the actions required to obtain the NPD products produced and delivered (Wheelwright & Clark, 1992). Therefore, density in information sharing is expected to evolve over time from a sparse network facilitating the creation and initial development of innovative proposals, leaving autonomy to actors, to a dense network facilitating production and delivery.

## **5. The Project Manager and Core Actors**

Because of the timely involvement of many different specialised actors from different groups, functions, and organisations, the information sharing NPD projects are characterised as involving multiple intra-organisational actors (project team members and employees from departments within the NPD organisation) as well as inter-organisational actors (such as suppliers and customers) who possess differentiated skills, experiences and motivations. All in all, there are many linkages to manage. To successfully integrate the different knowledge, the intra- and inter-organisational information sharing among actors must be coordinated and facilitated, which is often performed by PMs (Edmondson & Nembhard, 2009; Jepsen et al., 2012; Wheelwright & Clark, 1992).

The PM plays the most central role in the information sharing process during NPD projects (Clark & Fujimoto, 1991; Jepsen et al., 2012). Through his or her position, the PM is usually in close and regular contact with all of the project's



relevant actors and has unique knowledge of the “big picture” (Edmondson, 1999). Therefore, the PM is better able than any other actor to coordinate the intra- and inter-organisational actors’ diverse knowledge, skills and information during NPD projects and if necessary adapt the information sharing structure to changing requirements as the project unfolds (Kazanjian & Drazin, 2000).

However, during a large NPD project, the responsible PM is heavily burdened by both the intra-organisational and the inter-organisational actors’ communicating on a regular basis looking for information. For example, the PM is directly involved in many of the email exchanges and is thus exposed to massive and separate pieces of information circulating among NPD actors because the PM sends out emails and receives emails, both directly and as “cc”. In fact, PMs have been identified as the main knowledge-brokers in NPD projects and have been found to spend approximately 30% of their time facilitating information sharing among members of an intra-organisational project team (Kurul) without taking in to account the additional inter-organisational actors. The PM also spends time facilitating inter-organisational information sharing, and he or she may even facilitate information sharing in several NPD projects simultaneously.

Given the time constraints placed on the PM, the PM has been found to create an intra-organisational information sharing structure for the project team by delegating information sharing responsibilities to other core actors within the team (Clark & Fujimoto, 1991; Sarin & O'connor, 2009). However, no studies have investigated whether the PM receives support from other intra-organisational relationships (from internal actors outside the project team but within the organisation) or inter-organisational relationships (from external organisations, e.g., the customer or supplier). Such support might not only result in increased information sharing among actors (e.g., a higher intensity) but may also increase the possibility of information sharing among the most relevant actors in the NPD network because core actors from, for example, the customers know who the most relevant actors are in their own organisations.

Core actors are individuals who, in addition to the PM, dominate the information sharing structure in the NPD network (Kurul, 2008). It is actors who are central to the information sharing network, and they may have been formally appointed (Leenders et al., 2003) or have emerged by coincidence as informal managers of the information sharing among subgroups (e.g., the customer and developer company). Studies have found that core actors often seem to structure their work differently because rather than focusing on executing tasks on their own, they seek ways to integrate other actors into their work (Cross & Parker, 2004). Therefore, core actors tend to know or be linked to the most relevant actors from their functional area, department or organisation and know with whom to share information (Cross & Parker, 2004). Furthermore, they are more likely to be connected with other powerful actors potentially receiving information of higher quality (Ahuja, Galletta, & Carley, 2003). Core actors can thus assist with orchestrating information sharing and ease the communication burden of the PM (Clark and Fujimoto, 1991; Sarin & O'connor, 2009). Therefore, regardless of the PM's time constraints, the connections among actors will increase as will the chances of obtaining the required information at the right time for the NPD project (Kratzer, Leenders, & van Engelen, 2010).

By establishing relationships with well-positioned core actors from different functions or reference groups, the PM might be able to remove some of the barriers to information sharing. The core actors can assist the PM with gathering the right information for the NPD projects, which would have been quite difficult for the PM to gather otherwise. Information sharing can be difficult because each profession, department and organisation has its own language, cultural thought worlds, organisational responsibilities, and physical barriers (Hoegl et al., 2004). For example, a core actor from the construction department can ease the information sharing with other important actors from that department. Or an actor who categorises himself as a passionate engineer will be more likely to share information with another passionate engineer.

Finally, because the importance of different actors varies across the NPD project, the PM might be able to utilise relationships among core actors to identify other core actors for critical information sharing as the NPD project progresses (Burt, 2002). Then, instead of spending a lot of time identifying the core actors for the next NPD phases, the PM might be able to focus on other important matters.

## **6. The PM's relationships during the phases of NPD projects**

Studies have found that the PM takes an active role in linking the project team to the rest of the organisation (Hoegl & Weinkauff, 2005; Jepsen et al., 2012; Sarin & O'connor, 2009) and the development organisation with, for example, the customer organisation (Edmondson, 2003; Jepsen et al., 2012). Furthermore, previous research suggests that there are different phases in the course of an NPD project that require tailored PM behaviours (Hoegl & Weinkauff, 2005; Souder & Moenaert, 1992). However, including the author's own previous research (Jepsen et al., 2012), which focused on the PM's brokerage role, the literature has not emphasised the pivotal role of the PM in simultaneously structuring intra- and inter-organisational information sharing or studied this phenomenon during the different phases of an NPD project. Therefore, the next sections will attempt to combine the literature on the roles of the PM and core actors in intra- and inter-organisational information sharing during each of the NPD phases.

During the *concept phase* of the NPD project, initiating and structuring the project team's information sharing relationships with other intra-organisational (Hoegl & Weinkauff, 2005) and inter-organisational actors (Knudsen, 2007) are essential tasks for the PM. Intra-organisational research suggests that the PM should provide and support the information sharing structure. However, there must be room for autonomy in the intra-organisational actors (Hoegl &

Weinkauff, 2005). Too much project manager-mediated structuring might limit flexibility, innovation and creativity (Sarin & O'connor, 2009). Intra-organisational actors should be able to initiate their own relationships because this behaviour results in stronger working relationships (Hoegl & Weinkauff, 2005) and encourages the intra-organisational actors' self-confidence (Gerwin & Moffat, 1997).

The development of ideas and concepts requires that the project team share information with other actors outside the developer company such as actors from the customer (Lettl et al., 2006; Von Hippel, 1986) and the supplier (Knudsen, 2007) companies because these actors might have information or resources that are critical to the task (Brookes, Morton, Grossman, Joesbury, & Varnes, 2007). Information sharing with the customer is particularly relevant to meet product specifications and requirements (Jepsen et al., 2012).

Because it is also during this phase that agreements among intra- and inter-organisational actors regarding certain technical solutions are made, well-positioned core intra-organisational actors who have good connections inside the developer organisation (e.g., an R&D engineer from the construction department), with the customer (e.g., a key account manager from the sales department) and with the supplier (e.g., an engineer from the construction department who has had previous experience with suppliers) might be quite important during this phase.

In the *solution* development phase, the project team and the actors within the developer company should focus on internal problem solving and proceed with development work to meet project deadlines and milestones (Hoegl & Weinkauff, 2005; Kazanjian & Drazin, 2000). Too much interference with the project team can be disruptive and destructive (Sarin & O'connor, 2009) because too many different opinions about how to get things done might cost time and lead to initial schedule and cost slippage. Studies have found that intra-organisational actors complain that if they must engage in too many infor-

mation sharing activities, they do not have enough time left to tackle actual engineering work (Hoegl & Weinkauff, 2005). Although it is not clear from the literature, this phenomenon may also occur in an inter-organisational setting in which the research team consists of actors from the customer or supplier.

Jepsen et al. (2012) found that information sharing with the customer regarding specifications and requirements is important. However, communication with the supplier is especially important during the solution phase. The suppliers' involvement in the NPD phases depends on the supplier's role in the NPD project. If the supplier is an active and cooperative partner, early involvement is recommended (Jepsen et al., 2012); however, it might be sufficient for a supplier of spare parts to simply participate in later phases (Knudsen, 2007).

In the solution development phase, the PM plays a much more active role than in the concept phase (Jepsen et al., 2012). The PM must foster and facilitate information sharing among intra- and inter-organisational actors. Like the "heavyweight" project manager concept (Clark & Fujimoto, 1991), the PM is responsible for ensuring that information and agreements regarding customer needs and product specifications are understood and effectively shared among various actors (Jepsen et al., 2012). Furthermore, previously initiated relationships among intra- and inter-organisational actors in the concept phase must be maintained, and this task is performed by the PM. Intra-organisational core actors from the project team as well as inter-organisational actors from the customers can be quite valuable to the PM during this phase.

In the *testing phase*, the developed designs from the solution phase are implemented and tested. Therefore, intra-organisational information sharing among actors from the development and production departments is important in this phase of NPD projects (Olson, Walker, Ruekert, & Bonner, 2001).

The intra-organisational actors might need to change technical solutions or adjust their solutions because of negative results, which increases cost and time

pressures. To help the intra-organisational actors, the PM therefore can provide structure and support that address and resolve possible problems. Jepsen et al. (2012) found that the PM facilitates a lot of information sharing among members of the construction department during both the testing and delivery phases, indicating that the PM becomes responsible for the direct integration, motivation and coordination of important intra-organisational actors during this phase.

During the testing phase, the PM is responsible for informing the customer about the progress of the NPD project and obtaining customer feedback from tests of prototypes (Koufteros, Vonderembse, & Jayaram, 2005). Not only must the PM have a clear understanding of the competitive situation and technical risks of the customer (Clark & Fujimoto, 1991), it is also the responsibility of the PM to assess and develop an understanding of desirable product modifications or alternative applications during this phase.

By facilitating information sharing among intra-organisational actors and inter-organisational actors such as the supplier, the PM might be able to provide necessary information and resources to resolve problems and avoid delays. Furthermore, because it is the last chance to improve the final result of the NPD project, the PM should ensure that the gathered knowledge from the customer regarding the testing is transferred to the development department. Therefore, information sharing between the development department and the two groups of inter-organisational actors (suppliers and customers) becomes an important task of the PM, thus emphasising the importance of core actors in these functions. Relationships with intra-organisational actors from the development and production departments as well as inter-organisational core actors from the customer and supplier might be fruitful during the testing phase.

The main task of the PM in the *delivery phase* is to coordinate the delivery of the project to the customer. Before and during this phase, the PM facilitates information sharing among project team members and employees from the con-

struction and production departments to ensure that the project achieves its goals (Song & Swink, 2009).

Suppliers have been found to participate in the delivery process (Clark & Fujimoto, 1991) to ensure on-time delivery and the installation of equipment at customer facilities (Takeishi, 2001). Therefore, information sharing with the suppliers is particularly important. During the delivery phase, the last financial arrangements are made, and practical issues regarding the delivery must be coordinated, which means that information sharing with the customer is also important at this stage.

The above suggests that relationships with core actors in the financial or sales, production or construction departments are relevant to ensure that the project is delivered according to specifications and financial agreements and with the right documentation (Jepsen et al., 2012).

## **7. Empirical Setting and Data Collection**

To better understand the reality of intra- and inter-organisational information sharing among actors within NPD projects and how PMs' relationships with core actors can facilitate this, I will apply this framework to a case study of a high-cost, engineering-intensive, and customized NPD project.

### ***The Case***

The email correspondence which is analysed took place concerning a NPD project executed in a medium sized engineering and manufacturing company (referred to as the developer company) specialized in the development of process equipment for a world-wide industry. The project included several sub-projects, each aiming at developing a machine or a piece of equipment for the new production line. The degree of technology uncertainty of the sub-projects differed from low to high. Mostly, as in the project studied, NPD is done in close col-

laboration with a customer. In total, the case is an example of a high-technology, business-to-business, tailor-made development project.

The actors for the project are individuals from the departments at the developer company, the buyer and the user sections of the customer company, and suppliers of which several different were involved during the phases of the NPD project.

The customer in this case is a market leader in the industry. In relation to the project at hand, the customer can be regarded as consisting of two independent business units, the *buyer* and the *user*, both being relevant in this study. The *buyer* (*purchase and R&D*) is located in Europe and provides technical assistance for the development and optimization of production facilities for all subsidiary companies. The *user* is an independent manufacturing company (owned by the *buyer*) located in Russia. The objective of the project was to develop and produce a completely new production line for the *buyer* at a new plant in Russia.

At the developer company a temporary organisational unit was established for the project. The functional structure of this project team is what Clark and Wheelwright (1992) characterized as a “Heavyweight Team Structure”. Before start-up of the NPD project, the PM produced a detailed milestone chart over the phases of the NPD project. From this chart I, together with the PM, were able to identify four separate phases in the NPD project reflecting the phases in the project life cycle. For this task, I have used the NPD phases defined by Gray and Larson (2007): Concept development, solution development, testing, and delivery.

### ***Data Collection***

The analysis deals with the social-network concerning a particular project (see next section) and is based on archival material, the email exchange between actors concerning this specific NPD project. It is an analysis of all emails sent out



and received directly or as 'cc' by employees of the developer company throughout the period of a NPD project, which allows observation of what actually took place. Advantageously, because when NPD projects span across long periods of time it makes it difficult for the participants to recollect what happened, making survey data and other techniques based on recollection of the process unreliable.

For a social network researcher, emails are a rich network dataset to examine, and by analysing e-mails it is possible to reveal the factual structure in the information sharing process. An e-mail system hosted on a workplace server normally stores all interactions, therefore, its network data comprise a census of all interactions among system users (Ahuja et al., 2003). Of course this requires that all users store their e-mails in the system (in this case through an ERP system (SAP)). Even though this is not the situation for this case, the complete communication data may not be relevant, because the possibility that either "sender", the "direct recipients" or the "cc-recipients" have stored the e-mails is pretty high. In other words, many of the emails were obtained in two, three or more specimens depended on the number of involved intra- and inter-organisational actors in the email communication. Email data is more accurate than self-report data.

Regarding the data collection, relevant actors from the developer company were identified through the email communication of the PM. For this specific NPD project, the PM exchanged 3188 e-mails with different intra- and inter-organisational actors. Presumed that the PM is in contact with all relevant internal actors during the progression of a NPD project, I identified a total of 20 intra-organisational individuals, who have had an exchange of more than 5 e-mails with the PM regarding this NPD project. Unfortunately, it was only possible to obtain the emails of all of the relevant intra-organisational actors at the developer company. Thus, the sample size was the email exchange of 16 employees from the developer company yielding a response rate of 80 percent. In

the studies of networks this is a normal and expected response rate (Wasserman & Faust, 1994).

***The characteristics of the NPD project network***

The NPD project took place between August 2009 and June 2012. During this period a total of 8271 emails were identified. Clearing the dataset of duplicates resulted in 4658 emails exchanged among 373 individuals (see tables 1 and 2). In other words, a total of 373 individual actors were identified as sending emails to and from the project during the various phases.

The concept development phase lasted 550 days whereas the solution development, testing, and delivery phases lasted 142, 127, and 198 days, respectively (see table 1). Furthermore, the PM was involved in a total of 2678 emails during the various phases. The PM sent emails or received them directly or as a “cc”.

Some actors were connected, disconnected and reconnected during the different phases of the NPD project whereas others only participated in a single phase. This explains why the total is 98 and 275 different intra- and inter-organisational actors involved in the NPD project, respectively (see table 2). Furthermore, it shows that the PM was mostly involved in contact with external actors during the various phases.

<b>Phase</b>	<b>Concept</b>	<b>Solution</b>	<b>Testing</b>	<b>Delivery</b>	<b>Total</b>
Duration	<b>550 days</b>	<b>142 days</b>	<b>127 days</b>	<b>198 days</b>	<b>1.017 days</b>
Number of emails in the entire network	471 emails	1.501 emails	1.143 emails	1543 emails	<b>4658 emails</b>
Number of emails involving the PM	179 emails	754 emails	993 emails	752 emails	<b>2678 emails</b>

***Table 1: Descriptive results regarding duration and number of e-mails of the NPD phases***

Note: Numbers commented on are in bold

Tables 1 & 2 indicate that although the concept phase lasted for 550 days, this phase generated the fewest emails from participating intra- and inter-organisational actors. During the delivery phase most actors were involved, and the highest numbers of emails were exchanged.

<b>Phase</b>	<b>Concept</b>	<b>Solution</b>	<b>Testing</b>	<b>Delivery</b>	<b>Total</b>
Number of actors*	83	163	156	210	<b>373</b>
Internal actors**	40	60	47	64	98
External actors***	<b>43</b>	<b>103</b>	<b>109</b>	<b>146</b>	<b>275</b>
The PM's contacts with actors #	<b>33</b>	<b>98</b>	<b>82</b>	<b>86</b>	<b>162</b>
The PM's contacts with Internal actors ##	11	45	32	28	64
The PM's contact with External actors ###	22	53	50	58	98

**Table 2: Actors involved in the emails during the NPD phases**

Note: \*out of a total of 373 actors; \*\* out of a total of 98 internal actors; \*\*\* out of a total of 275 external actors

Note: # out of a total of 162 actors; \*\* out of a total of 64 internal actors; \*\*\* out of a total of 98 external actors

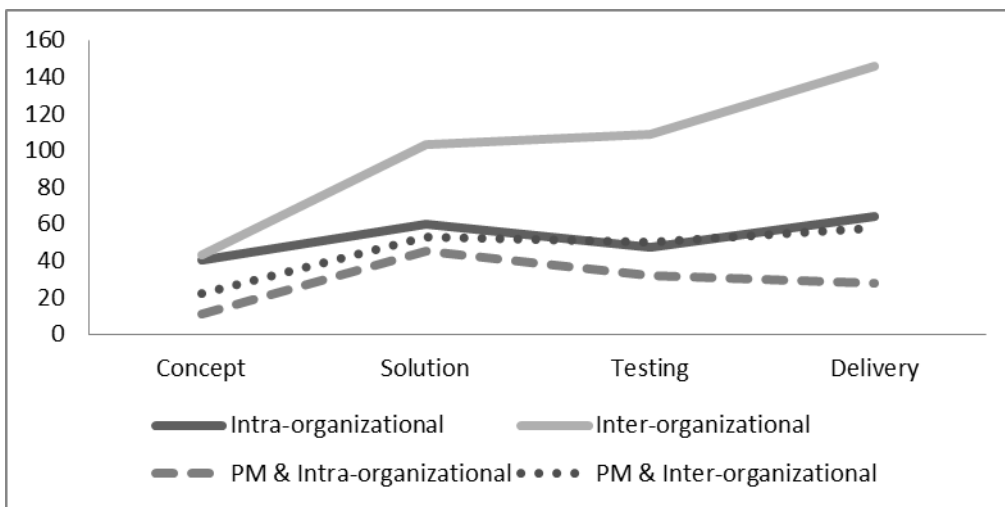
Note: Numbers commented on are in bold

Table 2 demonstrates that almost the identical number of intra- and inter-organisational actors were involved during the concept development phase. In the solution development phase, this number increased. However, during the testing phase, the number of intra-organisational actors decreased. The highest numbers of intra-organisational actors were involved in the delivery phase.

Throughout the phases of the NPD project, the external actors were involved, and the number of inter-organisational actors participating in each phase increased from 43 to 146 (see table 2). A network assessment revealed that the PM exchanged emails with 162 actors: 64 intra-organisational and 98 inter-organisational actors (see table 2). Thus the PM shared information with 43% of all actors involved in the NPD project. The assessment also demonstrated that a group of 15 actors had between 35 and 68 people exchanging emails with them on a regular basis regarding this NPD project. Figure 1 illustrates the evo-

lution of the involvement of both intra- and inter-organisational actors during the different phases of the NPD project.

These descriptive findings indicate that the structure of intra- and inter-organisational information sharing changes during the different phases of the NPD project. The findings also indicate that the PM plays the most central role in the information sharing network. However, to reach the entire NPD network, other actors were also determined to be central in orchestrating the information sharing during the phases of the NPD project.



**Figure 1: The distribution of intra- and inter-organisational actors during the NPD project**

The entire network intra- and inter-organisational actors compared with the intra- and inter-organisational actors the PM is directly involved with.

To build a solid foundation with which to answer the three research questions of this study, social network analysis (SNA) techniques provided analytical measures that described the statistical properties of networks and could be used in this analysis of information sharing in NPD projects.

## 8. Method of Analysis

To determine whether the structure and intensity of intra- and inter-organisational information sharing changes across the NPD phases, I first analysed the dataset using the *Quadratic Assignment Procedure (QAP)* in UCINET (Borgatti, Everett, & Freeman, 2002) to detect any structural differences (addressing R1), and afterwards I measured the intensity (addressing R2) in the different phases.

UCINET can calculate inter-network comparisons such as Quadratic Assignment Procedure (QAP) correlations. QAP calculates Pearson's correlation coefficient (as well as simple matching coefficients) between corresponding cells of the two data matrices. By repeating such calculations thousands of times, the QAP tests whether the association between two networks is statistically significant. This method investigates similarities in the relationships among the NPD actors across the phases by calculating correlations.

In social network research, the intensity of information sharing is determined by density. Density, which corresponds to the level of connections among the different actors in a network, is the number of actual links in the network as a ratio of the number of possible links in the network (Borgatti et al., 2002; Burt, 1992). Thus, the higher the density, the more information sharing occurs.

The roles of and the relationships with core intra- and inter-organisational actors by which the PM orchestrates information sharing are identified and evaluated through *Core-Periphery Structure* and *Network Centrality Measures* (addressing R3).

The *Core and Periphery* structure of the NPD network. Given a square data matrix, UCINET identifies a core/periphery structure by computing the degree of “coreness” for each node or actor in a matrix (continuous model). The concept

is that individuals in a group belong to either the core, which has a strong density of ties, or to the periphery, which has a low density of ties.

*Network centrality* has been defined as an actor's involvement in network relationships (Wasserman & Faust, 1994) and reflects the nature and level of connectedness among network actors. Centrality measures of actors' structural positions in a social network can be used to identify and evaluate core individual actors. Three particular aspects of network centrality have been widely adopted by network analysts: degree, closeness, and betweenness (Freeman, Roeder, & Mulholland, 1979). *Degree centrality* refers to the number of actors to whom a focal actor is directly connected. *Closeness centrality* is defined as the distance between an actor and other actors in a network including both direct and indirect linkages. Theoretically, actor closeness centrality captures actors' access to information flow in a network. *Betweenness centrality* is the degree to which an actor is positioned on the shortest path between pairs of other actors. Betweenness centrality is related to an actor's ability to control information flow between pairs of actors (Freeman et al., 1979).

## 9. Results

### *Structural changes in intra- and inter-organisational information sharing*

Regarding R1, the QAP correlations among the four information sharing networks (concept, solution, testing and delivery phases) within the NPD project (see table 3) were calculated. Correlations were performed to indicate a negligible association if less than 0.2, a weak association if between 0.2 and 0.4, a moderate association if between 0.4 and 0.7, and a strong association if over 0.7. Table 3 shows how similar/different the information sharing structures were during the phases of an NPD project.

Comparing the information sharing structure over time (during the phases) shows the concept-solution ( $r=0.597$ ) and the testing-delivery phases ( $r=0.57$ ) to be moderately similar, which implies that the information sharing structure

among actors has not changed dramatically over the course of these two sets of NPD phases. By contrast, the information sharing structures of the concept-testing ( $r=0.258$ ), concept-delivery ( $r=0.179$ ), solution-testing ( $r=0.290$ ), and solution-delivery ( $r=0.248$ ) phases are quite different. In other words, the information structures in these different time frames are quite different.

<b>Information sharing</b>	Concept phase	Solution phase	Testing phase	Delivery phase
Concept phase	1.000	0.597	0.258	0.179
Solution phase	-	1.000	0.290	0.248
Testing phase	-	-	1.000	0.570
Delivery phase	-	-	-	1.000

**Table 3:** *Average QAP correlations for information sharing relations during phases*

Tables 4 and 5 summarise the average QAP correlations between the intra-organisational and inter-organisational actors' relationships over the four phases. The results regarding the internal actors (table 4) show that the phases are moderately to highly correlated (between 0.568 and 0.860), especially in the solution-delivery phase. The solution-testing and the testing-delivery phases indicate a high similarity to one another. Only the results regarding the concept phase show that this phase distinguishes itself moderately from the solution, testing and delivery phases (0.568, 0.680 and 0.622, respectively).

<b>Internal actors</b>	Concept phase	Solution phase	Testing phase	Delivery phase
Concept phase	1.000	0.568	0.680	0.622
Solution phase	-	1.000	0.816	0.860
Testing phase	-	-	1.000	0.839
Delivery phase	-	-	-	1.000

**Table 4:** *Average QAP correlations for internal actors' information sharing relations*

The findings regarding the external actors' relationships show that the correlations among the phases are noticeably lower (ranging from 0.203 to 0.554) than the correlations among the phases regarding the internal actors (see table 5).

<b>External actors</b>	Concept phase	Solution phase	Testing phase	Delivery phase
Concept phase	1.000	0.203	0.542	0.291
Solution phase	-	1.000	0.336	0.554
Testing phase	-	-	1.000	0.395
Delivery phase	-	-	-	1.000

**Table 5: Average QAP correlations for external actors' information sharing relations**

Especially among the concept-solution ( $r=0.203$ ), concept-delivery, testing-solution ( $r=0.336$ ), and testing-delivery ( $r=0.395$ ) phases, there is an extensive distinction between the external actors information sharing networks. The phase's concept-testing ( $r=0.542$ ) and solution-delivery ( $r=0.554$ ) are more similar.

***Changes in the intensity of intra- and inter-organisational information sharing***

To address R2, the density of the networks was calculated. The density of a network (in this case an NPD phase) is zero if no connection is present between any of the actors in the network. On the other hand, if every single actor is connected to every other actor, the density is one (Wasserman & Faust, 1994).

<b>Density of phases</b>	Concept phase	Solution phase	Testing phase	Delivery phase
Density	0.151	0.185	0.418	0.492

**Table 6: Density measures of the NPD phases**

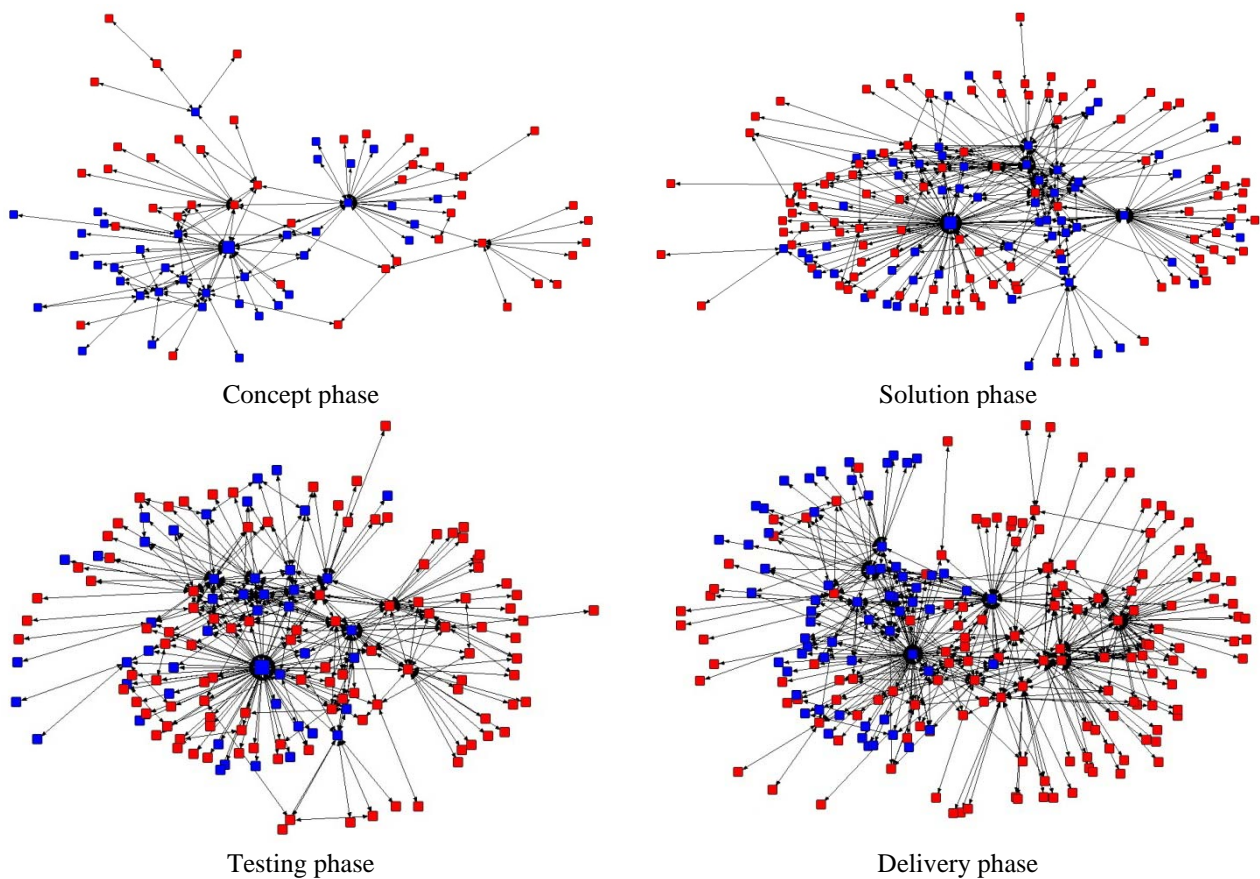
Table 6 shows that the delivery phase represents the phase with the best-connected network in the time period because 49% of all possible ties are pre-



sent. The concept phase is the most sparsely connected network because only 15% of all possible ties are present.

***Visualisation of the change in the structure and in the intensity of information sharing***

Finally, to visualise the findings, I depict the four network pictures of the NPD phases as assessed in the NPD project. The software program Netdraw (UCINET) visualises these networks using multidimensional scaling techniques to approximate the relative distances between the individuals in the network. The internal actors are represented by blue dots, the external actors by red dots, the relationships are depicted by the lines that connect the dots, and arrows indicate the direction of the relationship nomination. The network visualisations are depicted in figure 2. Enlarged versions of the visualisations are included in appendix A (see figure A.1, 2, 3, & 4). From the pictures, one may detect an underlying information sharing structure in all of the phases (with a good imagination, it looks like a fish viewed from the side, with a blue eye, fins and a tail).



**Figure 2: Network pictures to illustrate the dynamics of the NPD project**

Note: Blue dots = internal actors, Red dots = external actors

Overall, the network visualisations indicate that the concept phase is much less dense than the other three phases. However, previous results indicate that the solution phase is only slightly more dense (19%) than the concept phase (15%). However, the visualisation confirms that the delivery phase, followed by the testing phase, has the densest network of all the NPD phases. When considering the intra-organisational information sharing (represented by the blue dots), it is difficult to visualise any differences in the internal actors' information sharing structure, which supports the previous findings that intra-organisational information sharing is moderately similar across the NPD phases.

However, the structure of external actors (represented by red dots) differs from phase to phase. The structure in the concept phase looks quite different from the testing and delivery phases (confirming the QAP calculations). The red and blue dots in the network pictures render it possible to access the involvement of intra- and inter-organisational actors during the different phases.

In the concept phase, the distribution of intra- and inter-organisational actors seems equal. However, as the next network pictures become more and more filled with red dots, the number of external actors increases. The networks' pictures, therefore, confirm the descriptive results, the QAP calculations, and the intensity measures regarding intra- and inter-organisational information sharing.

### ***Core actors through whom the PM orchestrates information sharing during NPD phases***

From the networks' pictures (appendix A, figure A.1, 2, 3, & 4), it is also possible to identify core actors. The networks are designed so that the PMs are visually similarly centred by a relatively large blue dot in each network picture (the eye of the fish). It appears as if the PM connects and forms relationships among mostly intra-organisational actors in the concept and delivery phases and mostly among external actors in the solution and testing phases. Additionally, the network pictures indicate that certain intra- and inter-organisational actors are connecting and controlling the information sharing within the phases of the NPD project. These central intra- and inter-organisational actors are orchestrating the information sharing between both intra- and inter-organisational actors. When addressing R3 in the next section, I will elaborate on these findings by examining coreness scores and centrality measures of different intra- and inter-organisational actors.

As discussed earlier, the idea behind core/periphery and centrality calculations is to identify the main players in the NPD network. Because NPD projects require information exchange within and between different groups, some individual actors are more dominant in terms of orchestrating the information sharing

process. First, the results from the total NPD project are presented, and then the results from the concept, solution, testing and delivery phases are shown.

### *The total NPD Project*

From the core/periphery structure of the entire NPD structure for the total NPD project, I find the individual actors that belong in the *core* group of the network has a high density of ties, and the individuals that belong to the periphery has a low density of ties. The core group is a small subset of actors who participate more actively than the rest. As observed from the results the group consists of 30 people representing both intra-organisational actors from the developer company (D) and inter-organisational actors from the customer (C) and supplier (S) companies. From these the ten most central actors (in addition to the PM) in the total NPD project network were selected for further analysis by assessing the degree, closeness, and betweenness of these actors (see table 7). First, consider PB (the PM), KFT (D), SN (D), MM (D), NT (D), and JWK (D). These actors scored high on degree centrality, which means they received as well as distributed information to a large number of individuals. Consequently, these actors spent a lot of time communicating. Next, these actors (PB, KFT, SN, MM, NT, and JWK) also scored high on closeness centrality. In other words, they acquired information from many other actors rapidly by the use of intermediaries and short communication paths. paths connecting two actors. In effect, they had control over whether to share crucial information regarding the project.

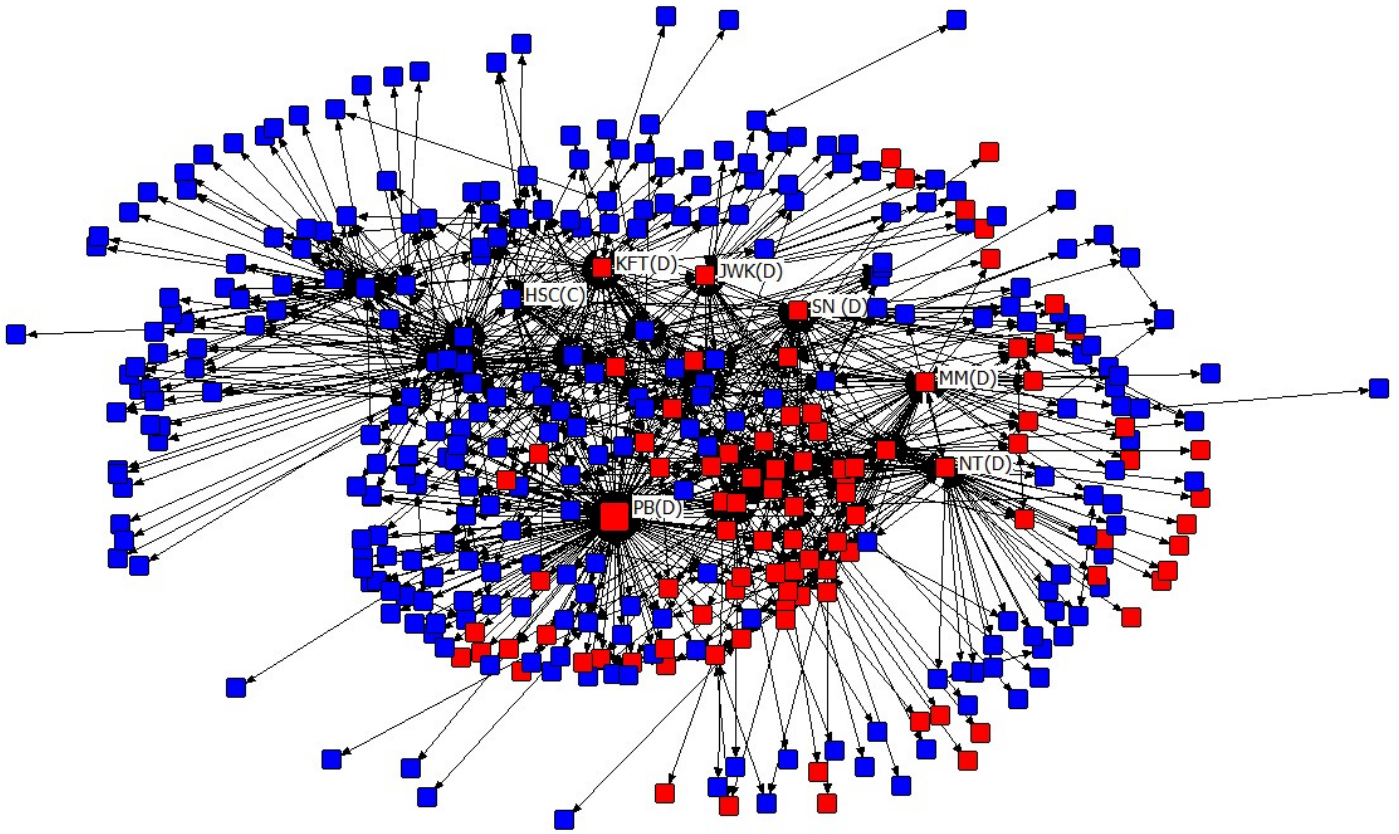
Name	Coreness	Degree	Closeness	Betweenness
<b>PB (PM)</b>	0.9542	<b>43.548</b>	<b>61.589</b>	<b>46.632</b>
<b>KFT (D)</b>	0.2020	<b>18.280</b>	<b>53.835</b>	<b>17.083</b>
<b>SN (D)</b>	0.1482	<b>14.785</b>	<b>49.012</b>	<b>8.683</b>
JS (C)	0.0789	8.065	46.211	2.352
<b>MM (D)</b>	0.0700	<b>13.441</b>	<b>48.312</b>	<b>8.341</b>
<b>HSC (C)</b>	0.0496	9.946	<b>48.564</b>	6.369
BT (D)	0.0489	7.258	45.091	3.274
LG (D)	0.0396	6.183	45.588	2.234
<b>JWK (D)</b>	0.0364	<b>11.022</b>	<b>47.328</b>	<b>10.263</b>
IS (D)	0.0361	1.882	40.216	0.061
<b>NT (D)</b>	0.0361	<b>15.323</b>	<b>48.062</b>	<b>12.471</b>

**Table 7: Centrality measures concerning the central actors for the total NPD project network**

Note: (PM) = project manager, (D) = developer company, (C) = customer.

Note: Numbers and names commented on are in bold.

Although HSC (C) distributed less information than the other six actors, this actor scored high on closeness centrality and had quick access to much more information than other, more peripheral actors. The six actors (PB, KFT, SN, MM, NT, and JWK) also scored high on betweenness centrality. The result implies that they were on many of the shortest communication and that they can be considered as information “gatekeepers” (see illustration of their position in the NPD network in figure 3).



**Figure 3: Network picture of the total NPD project**

Besides PB (D) there are five very central actors orchestrating the information sharing: KFT (D), SN (D), MM (D), NT (D), JWK (D), and HSC (C). Note: Blue dots = internal actors, Red dots = external actors

To decide which actors were the most significant in terms of orchestrating the information sharing process during each phase of an NPD project, I sorted the scores of each actor based on core/periphery and centrality measurements for each phase of the NPD project.

*The concept phase*

The principal group of core actors in the concept phase consisted of 20 people representing the developer (D), the customer (C), and the supplier companies (S). However, the ten most significant actors in the concept phase were mostly representatives of the developer with only a couple of actors from the customer company (see table 8). The analysis of the degree, closeness, and betweenness

of these actors reveals that PB (PM), LG (C), MM (D), NT (D), and JWK (D) scored high on degree centrality, on closeness centrality and (except NT [D]) on betweenness. In other words, they received and distributed information to a large number of actors rapidly by short communication paths and played a large role in connecting actors.

Name	Coreness	Degree	Closeness	Betweenness
<b>PB (PM)</b>	0.941	<b>39.024</b>	<b>56.552</b>	<b>48.111</b>
<b>LG (C)</b>	0.223	<b>18.293</b>	<b>50.000</b>	<b>19.257</b>
<b>MM (D)</b>	0.210	<b>13.415</b>	<b>40.796</b>	<b>10.612</b>
<b>NT (D)</b>	0.107	<b>12.195</b>	<b>41.624</b>	4.108
<b>JWK (D)</b>	0.061	<b>34.146</b>	<b>55.405</b>	<b>56.618</b>
<b>TR (C)</b>	0.042	8.537	<b>47.399</b>	<b>15.141</b>
HHJ (D)	0.032	10.976	39.048	2.139
HMH (D)	0.027	9.756	38.498	1.142
<b>AMJ (D)</b>	0.020	3.659	<b>42.051</b>	0.000
CN (D)	0.020	3.659	36.771	0.018

**Table 8: Centrality measures concerning the central actors for the concept phase**

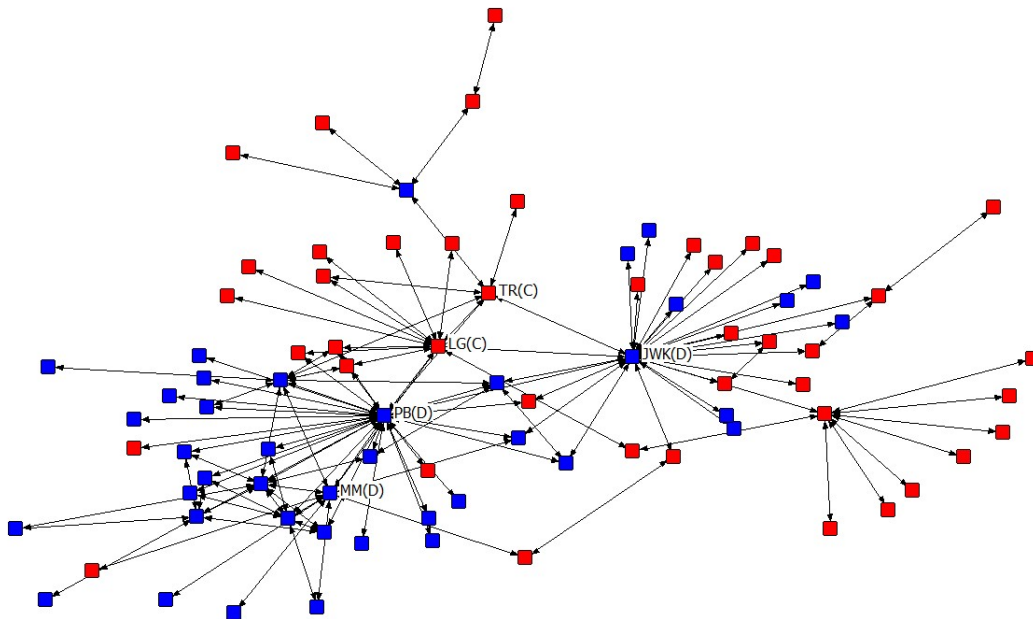
Note: (PM) = project manager, (D) = developer company, (C) = customer.

Note: Numbers and names commented on are in bold.

The actors AMJ (D) and TR (C) scored high on closeness, indicating that they were quite close to other actors in the network. Additionally, the actor TR (C) scored high on betweenness, implying that this actor played a large role in connecting actors.

The central role of an information gatekeeper is particularly visible for the actor JWK (D) in the network picture of the concept phase (see figure 4). Furthermore, JWK (D) conducted information to and from both intra- and inter-organisational actors. MM (D) and NT (D) primarily conducted information

towards internal actors. Finally, LG (C) primarily channelled information to external actors.



**Figure 4: Network picture of the concept phase**

Note: Blue dots = internal actors, Red dots = external actors

*The solution development phase*

In the solution development phase, the core group of actors consisted of 16 people, again representing all of the actor groups (D, C, & S).



Name	Coreness	Degree	Closeness	Betweenness
<b>PB (PM)</b>	<b>0.929</b>	<b>59.877</b>	<b>71.053</b>	<b>65.184</b>
<b>SN (D)</b>	<b>0.250</b>	<b>17.901</b>	<b>53.115</b>	<b>9.066</b>
<b>MM (D)</b>	<b>0.173</b>	<b>24.074</b>	<b>54.730</b>	<b>14.144</b>
JS (C)	0.095	7.407	<b>46.023</b>	0.758
<b>LG (C)</b>	<b>0.093</b>	<b>11.111</b>	<b>50.625</b>	<b>4.955</b>
<b>NT (D)</b>	<b>0.073</b>	<b>30.247</b>	<b>57.447</b>	<b>30.510</b>
HSC (C)	0.064	6.790	49.240	1.799
DP (C)	0.055	7.407	44.751	2.741
BG (D)	0.055	8.642	49.240	1.407
KS (D)	0.054	3.086	46.286	0.262

**Table 9: Centrality measures concerning the central actors for the solution phase**

Note: (PM) = project manager, (D) = developer company, (C) = customer.

Note: Numbers and names commented on are in bold.

The developer and customer companies were almost equally represented by the ten most central actors (see table 9). The analysis of the degree, closeness, and betweenness indicates that the actors PB (PM), SN (D), MM (D), LG (C), and NT (D) scored high on degree centrality, on closeness/centrality and on betweenness. The actor NT (D) played a central role in this phase.

### *The testing phase*

The core group of actors in the testing phase consisted of 17 core individual actors representing all of the actor groups (D, C, and S).

Name	Coreness	Degree	Closeness	Betweenness
<b>PB (PM)</b>	<b>0.868</b>	<b>52.258</b>	<b>67.100</b>	<b>60.151</b>
<b>SN (D)</b>	<b>0.275</b>	<b>20.000</b>	<b>49.521</b>	<b>12.179</b>
KS (D)	0.224	0.645	<b>40.260</b>	0.000
<b>KFT (D)</b>	<b>0.193</b>	<b>20.645</b>	<b>53.448</b>	<b>13.893</b>
<b>HMH (D)</b>	<b>0.134</b>	<b>42.818</b>	2.572	<b>11.739</b>
DM (C)	0.124	4.516	43.539	0.039
<b>DP (C)</b>	<b>0.102</b>	<b>14.839</b>	<b>50.162</b>	<b>8.548</b>
JS (C)	0.092	9.667	48.896	1.942
<b>MM (D)</b>	<b>0.089</b>	<b>11.613</b>	<b>49.679</b>	<b>7.639</b>
MLL (S)	0.081	9.677	44.413	2.906

**Table 10: Centrality measures concerning the central actors for the testing phase**

Note: (PM) = project manager, (D) = developer company, (C) = customer.

Note: Numbers and names commented on are in bold.

For the first time, an actor from a supplier company was one of the ten most central actors during the NPD project (see table 10). The analysis of the degree, closeness, and betweenness shows that the actors PB (PM), SN (D), KFT (D), DP (C), and MM (D) scored high on degree centrality, on closeness centrality and on betweenness.

### *The delivery phase*

In the testing phase, the core group of actors consisted of 10 individual core actors representing mostly the customer. During this phase of the NPD project, actors from the customer are particularly important (see table 11).

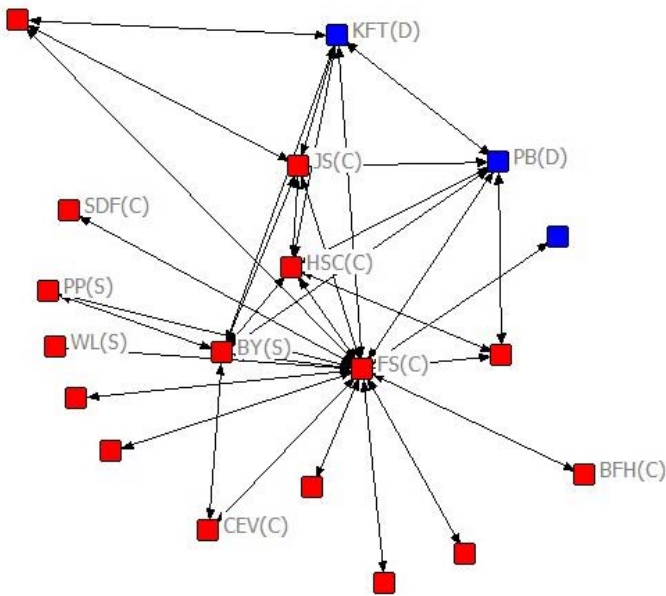
Name	Coreness	Degree	Closeness	Betweenness
<b>FS (C)</b>	<b>0.986</b>	<b>8.612</b>	<b>43.451</b>	<b>6.186</b>
CEV (C)	0.085	0.957	32.203	0.000
<b>HSC (C)</b>	0.074	<b>9.091</b>	<b>45.534</b>	2.551
<b>BFH (C)</b>	0.063	0.478	30.334	0.000
<b>KFT (D)</b>	0.060	<b>26.794</b>	<b>56.640</b>	<b>29.344</b>
<b>BY (C)</b>	0.050	<b>7.656</b>	<b>45.934</b>	<b>6.365</b>
PP (S)	0.047	1.914	35.726	0.089
<b>PB (PM)</b>	0.031	<b>40.670</b>	<b>58.543</b>	<b>44.527</b>
<b>WL (S)</b>	0.031	<b>0.957</b>	<b>34.375</b>	0.068
SDF (C)	0.021	<b>5.742</b>	<b>37.455</b>	0.497

**Table 11: Centrality measures concerning the central actors for the delivery phase**

Note: (PM) = project manager, (D) = developer company, (C) = customer.

Note: Numbers and names commented on are in bold.

The analysis of the centrality measures indicate that the actors PB (PM) and KFT (D) scored high on degree centrality, on closeness centrality and on betweenness. The two external actors HSC (C) and FS (C) scored high on closeness centrality but not particularly high on degree centrality or betweenness. They quickly received information from many actors through intermediaries although they were not directly connected to many actors, nor did they have special control over communication paths.



**Figure 5: Network picture of ego network of FS (C) in the delivery phase**

Although the external actor FS (C) was not part of the core group for the total NPD project, this actor played an extremely important role in the delivery phase. The Ego Network picture of FS (C) indicates that this actor was important because of his connections to the “right” actors. In other words, FS (C) had a direct link to the other core actors of this phase (see figure 5).

*Intra- and inter-organisational core actors*

Three internal core actors were part of the core group for the entire project and during two of phases: KFT, SN and MM (see table 12). The last two internal core actors were part of the core group of actors for the entire project and of the core group for at least one of the four phases (JWK & BT).

Core Group	Total Project	Concept I	Solution II	Testing III	Delivery IV	Present in
PB (PM)	X	X	X	X	X	I, II, III & IV
NT (D)	X	X	X	X		I, II & III
KFT (D)	X			X	X	III & IV
SN (D)	X		X	X		II & III
MM (D)	X		X	X		II & III
JWK (D)	X	X				I
BT (D)	X			X		I
Number of internal actors	7	2	4	6	2	

**Table 12: Core internal actor represented in the NPD project**

Note: Selected core actors are present in the core group for the total project and at least one of the NPD phases

Although KFT (D), SN (D), and MM (D) were not central actors in all of the NPD phases, their importance in particular phases shows in figure 6. KFT (D) was quite central in the testing phase, SN (D) in the solution and testing phases, and MM (D) in the concept and solution phases.

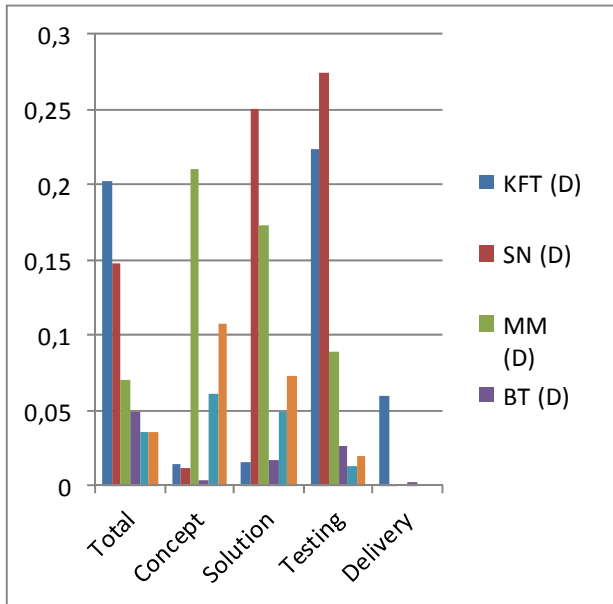
The findings regarding the external core actors show that LG and HSC were the core actors and a part of the core group for the entire project and during three project phases (table 13).

Core Group	Total Project	Concept I	Solution II	Testing III	Delivery IV	Present in
HSC (C)	X		X	X	X	II, III & IV
LG (C)	X	X	X	X		I, II & III
JS (C)	X		X	X		II & III
DP (C)	X		X	X		II & III
TR (C)	X	X				I
Number of external actors	5	2	4	4	1	

**Table 13: Core external actors represented in the NPD project**

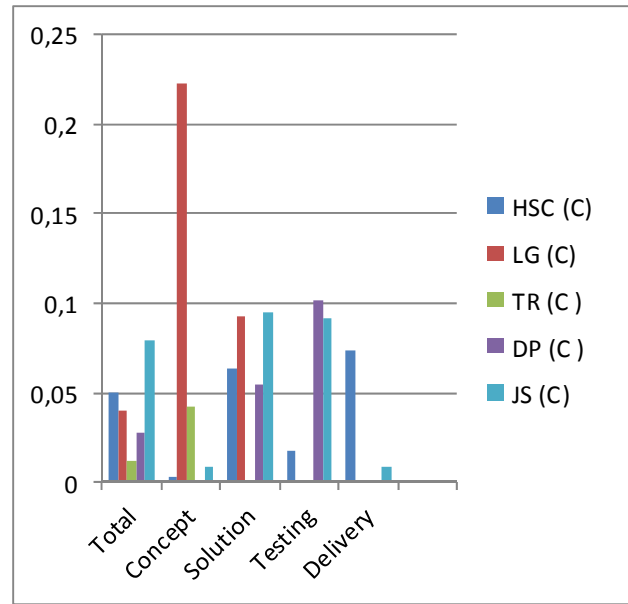
Note: Selected core actors are present in the core group for the total project and at least one of the NPD phases

Two external core actors were part of the core group for the entire project and during two of the phases: JS and DP. The rest of the external core actors were either part of the core group of actors for the entire project or in one of the four phases.



**Figure 6: The importance of core internal actor during the NPD project (measured by coreness score)**

Note: PM is removed because of the PM's high score on coreness (0,929), which would radically change the picture



**Figure 7: The importance of core external actor during the NPD project (measured by coreness score)**

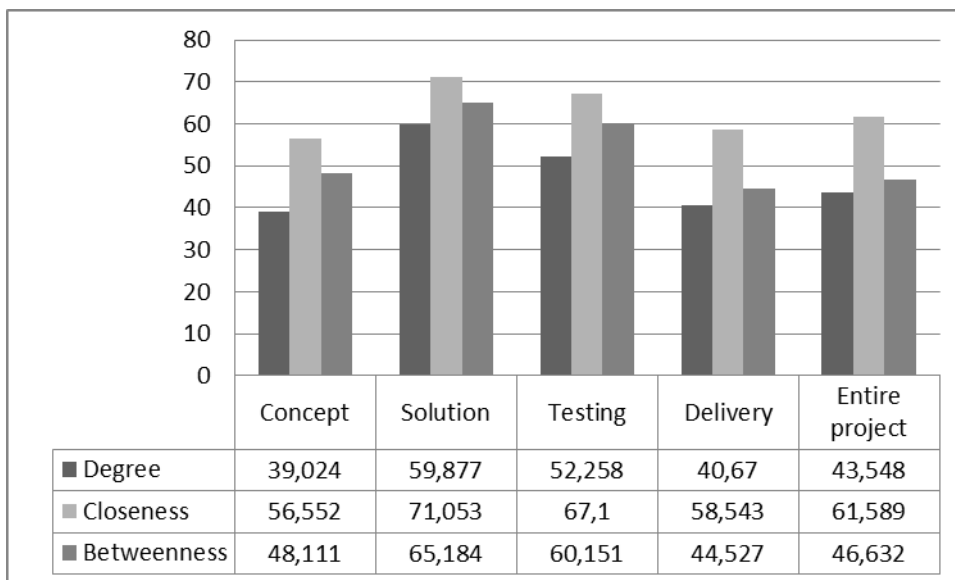
Note: FS is not part of the figure because this actor is not part of the core group for the total project, further the coreness score of FS (0,986) would radically change the figure

Figure 7 indicates that LG (C) was central to the concept phase and to the solution phase of the NPD project. The external actors JS (C) and DP (C) were both central to the testing phase, and JS (C) was particularly important to the solution phase. HSC (C) was central throughout all phases of the project except for the concept phase. Thus, one internal core actor (NT) and two external actors

(HSC and LG) were present (in the core group of actors) in all groups and through three of the NPD phases. Furthermore, two internal actors (SN and MM) and two external actors (JS and DP) were part of the core for the entire project and during two of the NPD phases. The remaining actors, two internal actors (JWK and BT) and one external actor (TC), were part of the core for the total project and only one of the NPD phases.

*The PMs' initiated relationships during NPD phases*

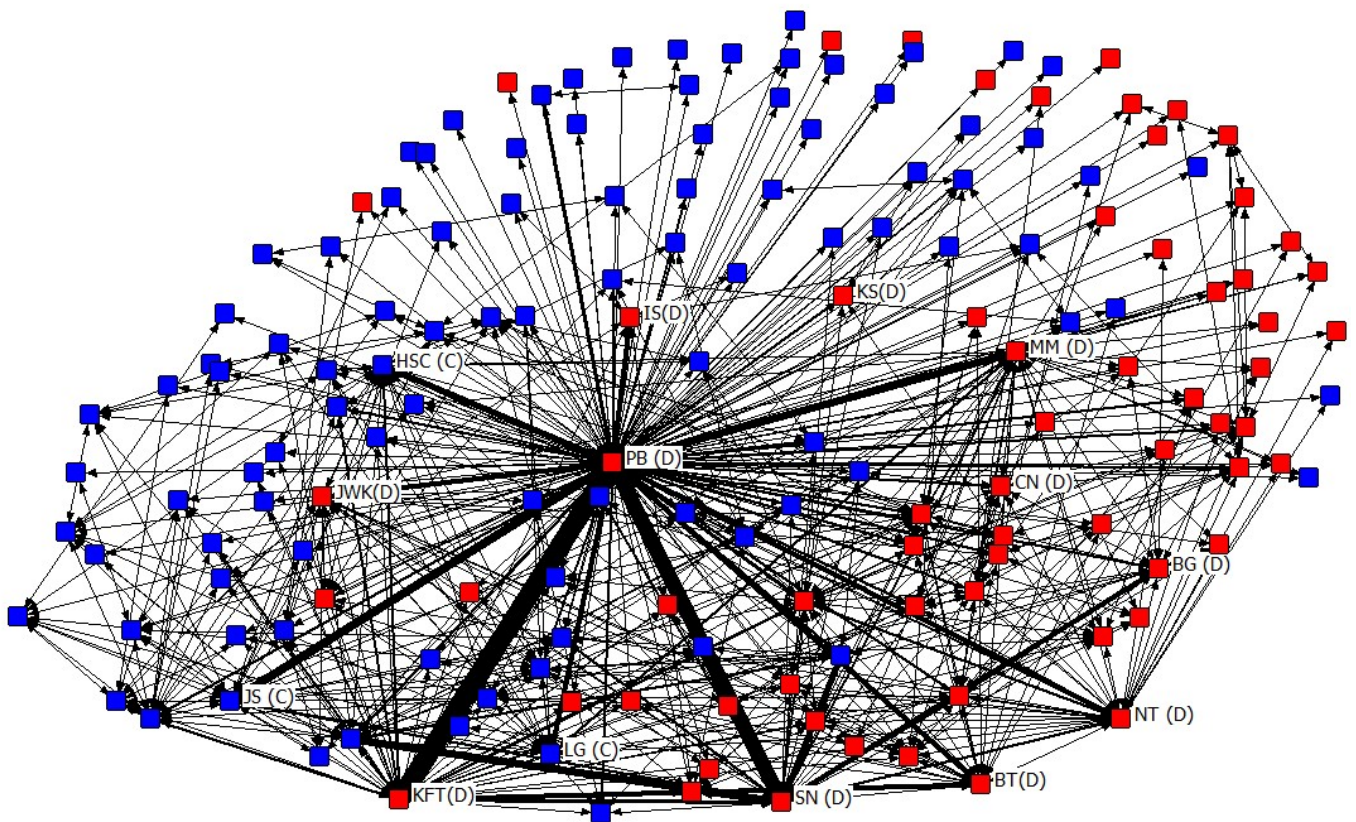
The findings indicate that one internal core actor, the PM, is the most important actor in the entire project and during all of the phases (see figure 8).



**Figure 8:** *The centrality measures of the PM during NPD phases*

The centrality measures indicate that the PM's number of direct contacts (number of actors) increased during the concept (39) and solution (60) phases whereas the number of actors decreased during the testing (52) and delivery (41) phases. Additionally, number of involved actors increased during the progression of the NPD project (from 83 to 373 actors) (see table 2 on page 133).

Figure 9 shows the PM's strong relationships with some of the identified intra- and inter-organisational core actors in the total project. However, the visible core actors were those to whom the PM sent emails, indicating that these were the actors that the PM had a direct need to be involved with, in other words, the actors he actively initiated a relationship with during the NPD phases. The network picture clearly illustrates the strengths (by the size of the line between the actors) of the PM's relationship with each of the core external and internal actors.

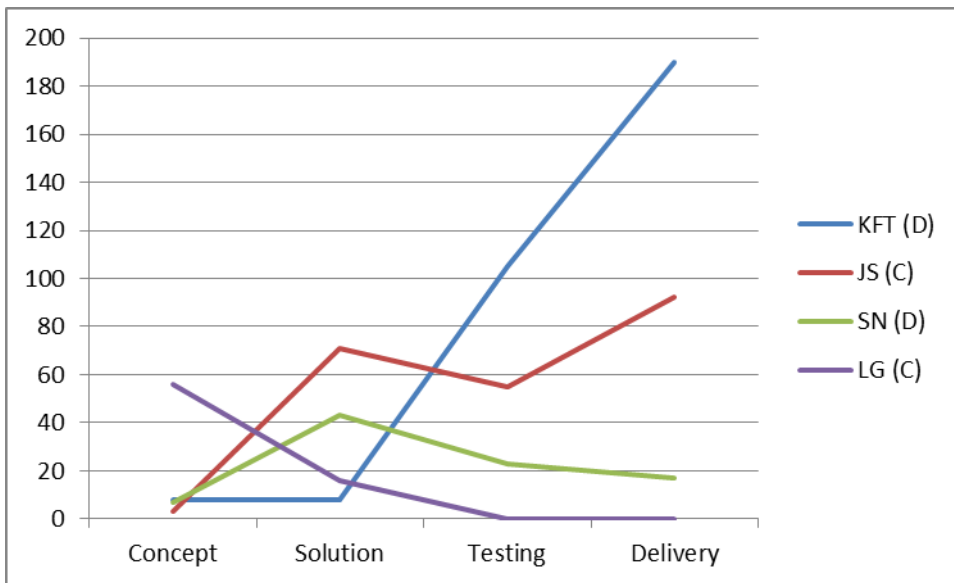


**Figure 9:** *Ego network of PM relations with visible core actors*

Figure 10 shows that the PM sent most of his emails to KFT (D), JS (C), SN (D) and LG (C). It further shows, that the PM only initiated a relationship with one core inter-organisational actor from the customer company (LG) during the concept phase. In the solution phase, two important intra-organisational rela-



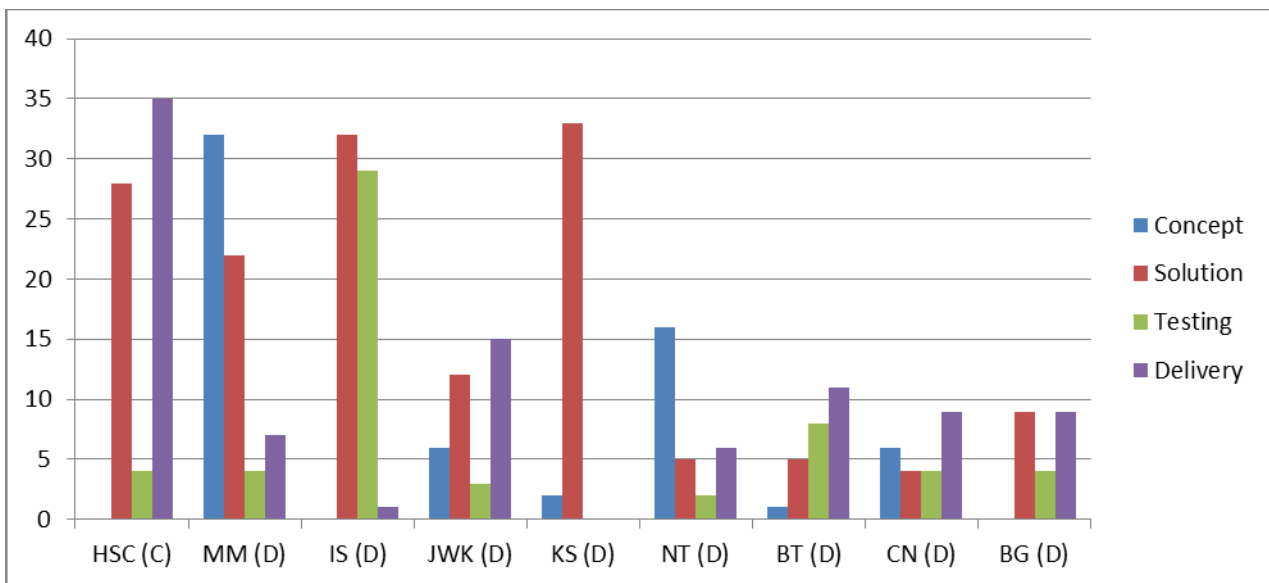
tionships (SN & KFT) and the second inter-organisational relationship (JS) with the customer company were initiated. The results show that the importance of the first inter-organisational relationship declined as the second inter-organisational relationship increased during the solution phase. The inter-organisational relationship with JS from the customer company remained important during the course of the NPD project, which is also the case for the intra-organisational relationships with KFT and SN. However, the importance of the latter decreased during the progression of the phases.



**Figure 10: The four most important core actors for the PM**

Figure 11 demonstrates that nine other relationships with core actors were considered to be relevant by the PM to facilitate information sharing during the NPD project. Only one relationship with a core inter-organisational actor (HSC (C)) was initiated and maintained during the course of the last three NPD phases. The rest of the relationships were with intra-organisational actors, and these relationships were initiated during different phases and their relevance changed during the course of the NPD project.

In sum, during the concept phase, the PM initiated inter-organisational relationships in collaboration with core intra-organisational actors from the sales and construction departments. However, during the last three phases (the solution, testing and development phases), the PM's main task was to ensure and maintain the external information sharing structure by establishing relationships with core intra-organisational actors who had both intra- and inter-organisational contacts.



**Figure 11: Other relevant core actors for the PM**

## 10. Discussion

This study emphasises the importance of the PM in information sharing among intra- and inter-organisational actors during the phases of an NPD project, and at the beginning of this paper, I raised research questions regarding whether (R1) the structure, and (R2) the intensity of information sharing among actors changed during NPD phases, and (R3) which core actors supported the PM in orchestrating information sharing during the NPD phases.

The response to research question one is that the structure of information sharing changed during the NPD phases. More precisely, the results show structural differences in information sharing when comparing the structure of simultaneous intra- and inter- organisational information sharing in the concept phase with both the testing and delivery phases. This phenomenon also occurs when comparing the solution phase with both the testing and delivery phases. Notably, the structure in the inter-organisational information sharing in the concept phase was significantly different from the solution and delivery phases but not from the testing phase. Furthermore, the inter-organisational information sharing in the testing phase was significantly different from the solution and the delivery phases. These results contribute to the literature on intra- and inter-organisational information sharing because this research considers the dynamic perspective of the NPD project and the structural differences in intra-organisational, inter-organisational, and combined intra- and inter-organisational information sharing.

Answering research question two shows that the intensity changed during the NPD phases. Actually, the intensity in information sharing increased during the progression of the NPD project. In both the concept and solution phases, the network was sparsely connected. However, in the testing and delivery phases, nearly 50% of all actors were directly connected with one another. It showed that the results regarding the solution phase were not visible from the network pictures.

As observed from the results, the intensity of information sharing increased as the NPD progressed. In other words, increasingly more intra- and inter-organisational actors were connecting during the NPD phases to share information. The descriptive data showed that the network size increased, and it is reasonable to assume that the structural diversity increased accordingly. Especially during the last three phases of the NPD project, an increasing number of inter-organisational actors became involved. In other words, information sharing in the NPD project became more and more complex. Numerous external ac-

tors representing diverse functions in the supplier and customer organisations, often located in different countries (e.g., Russia), were being accessed and involved in the NPD project. This supports previous findings that the development of NPD projects requires competences and resources that often exceed the capacity of a single PM (Clark & Fujimoto, 1991), a single team (Hoegl et al., 2004) or even the largest company (Kazanjian & Drazin, 2000).

However, the results also show that more and more intra- and inter-organisational actors are becoming connected during the course of an NPD project. Notably, in the testing and delivery phases, nearly 50% of all involved actors were directly connected to one another whereas only 15% and 19% of the intra- and inter-organisational actors were connected in the concept and solution phases.

This result, combined with the results regarding the significant changes in the structure of intra- and inter-organisational information sharing, suggests that the two early phases (the concept and solution phases) and the two latter phases (the testing and delivery phases) are almost identical with respect to information sharing structure and intensity. As shown, the two sets of phases, concept-solution and testing-delivery, have moderately similar information sharing structures (respectively 0.597 and 0.570).

Notably, although the network size and diversity increased, the intra- and inter-organisational actors were becoming even more connected. One would assume that although it is difficult, it would have been easier for 83 actors (from the concept phase) to become fully connected than the 210 actors from the delivery phase (in which 103 actors were actually fully connected).

Surprisingly, the structures of the inter-organisational information sharing in the concept-testing and solution-delivery phases were moderately similar. Furthermore, I found that the number of intra-organisational actors involved in the concept phase (40) and the testing phase (47) and involved in the solution phase

(60) and the delivery phase (64) were almost identical. Perhaps interesting implications can be inferred from this finding, but future research must investigate whether this finding is important and if so, try to explain what it means for project management in NPD projects.

### **The PM and Core Actors**

The third and most central research question focused on the “PM’s relationships with core actors” (Clark & Fujimoto, 1991; Sarin & McDermott, 2003), which, although recognised, has not been examined directly in relation to intra- and inter-organisational information sharing. The evidence indicates that the PM’s relationships with core actors resulted in a successful information sharing process during the NPD project. Unexpectedly, the results not only identified intra-organisational core actors but also showed that several inter-organisational actors played an important role in supporting the information sharing process with the PM during the different NPD phases.

#### *The PM as the Core Actor*

As in prior research (Sarin & O’connor, 2009), the PM was also in this case identified as the most core actor in the entire NPD project. The PM received and distributed emails to the largest number of individuals in the network. Furthermore, the PM received information sooner than other actors and occupied many of the shortest communication paths between two actors. During the first phases of the NPD project, the PM connected many intra-organisational actors. However, during the last phases, the findings surprisingly show no significant differences in the information sharing structure among intra-organisational actors, indicating that these actors now were familiar with one another and exchanged the information required for meeting the challenges of the NPD project with one another directly without going through the PM. In other words, during the late phases of the NPD project, the intra-organisational actors did not require the coordination of the PM to assure the proper information sharing.

The findings show that the PM, instead of facilitating the intra-organisational information sharing, ensured that the intra-organisational actors shared the appropriate information with inter-organisational actors to facilitate internal development. The PM identified the inter-organisational actors and coordinated the information sharing process between them and the intra-organisational actors. The results of this study clarify the facilitation of information sharing among intra- and inter-organisational actors as the most important task of the PM. This study indicates that the PM is mostly external-oriented because the PM mostly exchanged emails with inter-organisational actors. In other words, the PM structured the information sharing among relevant intra- and inter-organisational actors. For example, the PM gathered and processed information from the customers regarding product specifications and requirements and then either connected or disseminated this information to the right intra-organisational actors to ensure that these requirements would be met. In other words, the intra-organisational actors need not spend time identifying, initiating or maintaining contact with relevant external actors to secure the necessary information. The intra-organisational actors can instead focus on internal problem solving, proceeding with development work and delivery plans to meet project deadlines. The PM's structuring of information sharing with external actors thus became essential for the NPD project because this information sharing might not only distract intra-organisational actors but might also be quite resource-consuming. This argument is partially confirmed by the findings of Hoegl and colleagues (2004), who found that project team members' information sharing with actors outside the team negatively affects project team effectiveness (within time and budget restrictions) and efficiency (Hoegl et al., 2004). However, Hoegl et al. (2004) only focused on information sharing within and between teams (multi-team projects) and departments of a given NPD organisation. Therefore, the findings of this study contribute to existing literature by including both the intra- and inter-organisational perspectives in the analysis because they also shows that too much irrelevant information sharing with irrelevant inter-organisational actors outside the developer company might best be avoided.

All in all, the results show that the PM received and distributed a lot of information to a large group of both intra- and inter-organisational actors, especially during the concept and solution phases of an NPD project. Consequently, the PM spent a lot of time on information sharing. The PM takes the time to understand, assimilate and process the received information. Regarding the distributed information, the PM must spend time guaranteeing that the data transferred are as accurate as possible and distributed to the right people because a great number of individuals depend on it for the successful development of the NPD project. On one hand, the PM is in an advantageous position in the information sharing network. However, as the number of involved external actors increased during the testing and delivery phases of the NPD project, the PM became busier. Not only would he be quite difficult to contact, he might also become overloaded with information. As argued by Boisot (1995), individuals can process only a certain amount of information because of limited resources, energy, time and cognitive capacity. Therefore, there is a risk that important information may be overlooked by the PM because of information overload (Sarin & O'connor, 2009). Furthermore, the involvement of more new inter-organisational actors rendered the project quite complex, and the PM faced difficulties maintaining the overview of relevant actors. Consequently, actors may receive important information too late, which would require them to discard previous work in light of this “new” information and start over again (Leenders, Kratzer, & van Engelen, 2007), which may result in not meeting the deadline or the requirements of the customer and exceeding the budget.

Notably, the PM in this case avoided creating a bottleneck. The centrality measures show that during the last phases, the PM had relatively less direct contact with actors compared to the increasing number of newly involved actors. In other words, although the network size and information sharing density increased, the PM's direct network of contacts remained stable. These results combined with the results from the core/periphery analysis show that the PM received assistance from other core actors to orchestrate the information sharing.

### *The PM's Relationships with Core Actors*

The results indicate that the PM directly initiated relationships with ten quite important core intra-organisational actors. These core actors not only represented the different departments of the developer company (construction, production and sales departments) but also various areas of expertise. They were central to the NPD project in terms of their being closely linked to a large number of NPD project actors and able to control the intra- and inter-organisational information sharing. Consequently, a relationship with these core intra-organisational actors reduced the amount of time the PM spent coordinating information sharing. This assistant's role of other intra-organisational actors has been mentioned in previous research (Clark & Fujimoto, 1991; Sarin & McDermott, 2003) but has not been fully examined. Therefore, the results of this study advance our understanding of who these intra-organisational core actors are and when they assist the PM with the information sharing process.

Additionally, this study shows that the PM not only established relationships with intra-organisational actors but, very unexpectedly, established relationships, with inter-organisational actors from both the customer and supplier companies. This surprising finding suggests that three core inter-organisational customer actors (JS, LG and HSC) played an important part in orchestrating the information sharing process. The PM thus initiated relationships with core inter-organisational actors to optimise the information sharing process with inter-organisational actors. When people come together for the first time to engage in an NPD project, they do not learn about one another's skills and abilities until late in the project (Cross & Parker, 2004). This phenomenon becomes even more evident when intra-organisational actors and PMs must share information with different actors outside the boundaries of the developer company. This finding can be interpreted as follows: the PM establishes inter-organisational relationships with considered core actors, which creates an awareness of the expertise in the network outside the developer company as well an understanding of when and why to share information with these external actors (Cross & Parker, 2004). As a side effect, a strong relationship with a core actor might al-



so provide the customer with a better understanding of the type of information the developer company is seeking and further improve information sharing. The findings also show that information sharing with inter-organisational actors increases as the NPD project progresses and that the core inter-organisational actors become increasingly important. Evidently the PM succeeds in establishing the correct relationships as the network size and density increase. Thus more and more inter-organisational actors connect to the developer company without direct facilitation of the information sharing process by the PM. This argument is also supported by the finding that inter-organisational structural relationships change significantly during the different phases of the NPD project. Finally, the findings show that the information sharing process in the late phases (especially in the delivery phase) of the NPD project, supported by the PM's design of a network of external core actors, surpassed the relationships with internal core actors. In the delivery phase, the core group consisted of 80% external actors, and an external actor (FS) from the customer company was now the "most" core actor. Therefore, the inter-organisational core actors, particularly FS, were quite visible and strongly connected to other core inter-organisational actors during this NPD phase. The centrality measures show that the PM remained the most central actor in the delivery phase. However, the PM was no longer the most "core" actor, and the other intra-organisational core actors were also losing importance. This finding suggests that FS could fulfil the role of the PM in this phase and render the PM obsolete. Research has emphasised that the PM plays a significant role in acquiring knowledge in the NPD process (Sarin & O'connor, 2009) through his brokerage role (Jepsen et al., 2012) and particularly by his external relationships (Elkins & Keller, 2003). In addition to the PM, other significant individuals in the NPD process have been identified for having ties not only inside but especially outside the developer company such as the boundary-spanner (Ancona & Caldwell, 1992b), the technological gatekeeper (Allan, 1977), and the relationship promoter (Walter & Gemünden, 2000). The relationship promoter (Walter & Gemünden, 2000) helps overcome the barriers of not knowing external actors through his inter-organisational networks. However, none of these studies has taken into account that the PM establishes rela-

tionships with core inter-organisational actors during NPD projects to promote information sharing with other external actors. Thus, it is a substantive contribution of this study that the PM's relationships with core external actors can be used as important enablers of the information sharing process. Furthermore, the results suggest that with limited effort the PM is able to maintain his central position facilitating, monitoring and controlling the information sharing process through his relationships with core actors.

## **11. Conclusions and Limitations**

Through an analysis of email data representing the real activities of actors, the current paper aimed at contributing to the further understanding of changes in the structure and intensity of intra- and inter-organisational information sharing among actors during the phases of an NPD project. This paper also focused on how NPD actors access and gain information from the inside and outside and across different organisational boundaries through a PM's relationships with individual core actors on a day-to-day basis.

The main conclusion of the study is that the information sharing process during an NPD project is a complex, dynamic process, involving the integration of a large number of actors (in this case 373 actors) of diverse functions from different organisations.

The findings provide evidence that the structure and the intensity in the information sharing processes are greatly influenced by the PM's relationships with core intra- and inter-organisational actors during the NPD phases. In the concept and solution-delivery phases, the intensity of information sharing was low, and the PM's direct contacts with intra- and inter-organisational actors were high. During the testing and solution phases, the intensity increased as the PM's direct contacts with both intra- and inter-organisational actors decreased. When comparing the structure of the intra- and inter-organisational information sharing of the first two phases with the last two phases, this paper shows that there

was a significant difference between these two timeframes. At the same time, the results show that the PM established most of his relationships with the intra- and inter-organisational core actors during the concept and solution phases and only chose to maintain close contact with a few of them during the last two phases of the NPD project. The PM's initiated relationships with core actors during the first two phases of the NPD project evidently resulted in higher information sharing intensity among NPD actors during the last two phases without compromising the PM's central position in the NPD network.

A major contribution of this study is the analysis of longitudinal objective email data, which provides two significant methodological additions to prior research. First, this study is based on email data that represent activities that have actually occurred. These data, as opposed to interview or survey data, are free of cognitive and psychological biases. Additionally, unlike many prior studies that have studied information sharing from a static perspective using cross-functional data, this study provides a dynamic perspective because it is based on longitudinal data.

Thus, this study provides new insights and extends the existing understanding of information sharing during an NPD project. However, the results of the study should be interpreted cautiously because of several limitations. First, it should be noted that the results do not provide generalisable truths applicable to any context because this study drew data from only a single project in a specific industry. Second, the results of this study do not present the full picture of the communication among actors because it has only been possible to gain access to the email exchange of sixteen intra-organisational actors. Communication using other media, for instance, meetings, phone calls, etc., is not considered here. However, because the actors were geographically dispersed in this project, the email correspondence most likely reflected the underlying pattern of communication.

## **Practical implications**

Although the findings must be interpreted cautiously and confirmed by other studies, it is reasonable to conclude that the PM's relationships with both core intra- and inter-organisational actors in information sharing are significant. Thus, to improve the information sharing process, the PM must identify external core actors (particularly from the customer) with whom he/she can initiate a useful relationship in the early phases of the NPD project. These core external actors act as intermediaries who can guide and promote the information sharing to other core actors within their organisation. This behaviour enables a better interaction among intra- and inter-organisational actors and ensures a successful information sharing process during the NPD phases. The PM should reach outside the project team to contact and establish relations with well-positioned core actors to ensure a successful information sharing process (Clark & Fujimoto, 1991). These core individuals, referred to as core actors, must orchestrate the information sharing with peripheral intra- or inter-organisational actors with whom the PM does not have contact. The network pictures of the different phases provide a powerful tool to visualise the core actors for the PM and support information sharing for project management.

## **Future research**

The results regarding the external actors' role in information sharing during the progression of the NPD project generated some intriguing questions for further studies. For example, how do external actors achieve their central position in the NPD network? Is it because of their formal role in the customer project organisation, or is it because of other circumstances? Similar to the PM of the developer company, the most central external actors (the PMs of the customer organisations), could also be forced to create relationships with other external and intra-organisational actors. Therefore future research might discover an identical pattern at external organisations. Finally, as this study is based on numbers of e-mails and not contents, there is no knowledge on what the information sharing is about. An interesting area of further research would of course be to

look into the e-mails in more detail to learn about this communication. This research could be supported by literature on boundary management theory.

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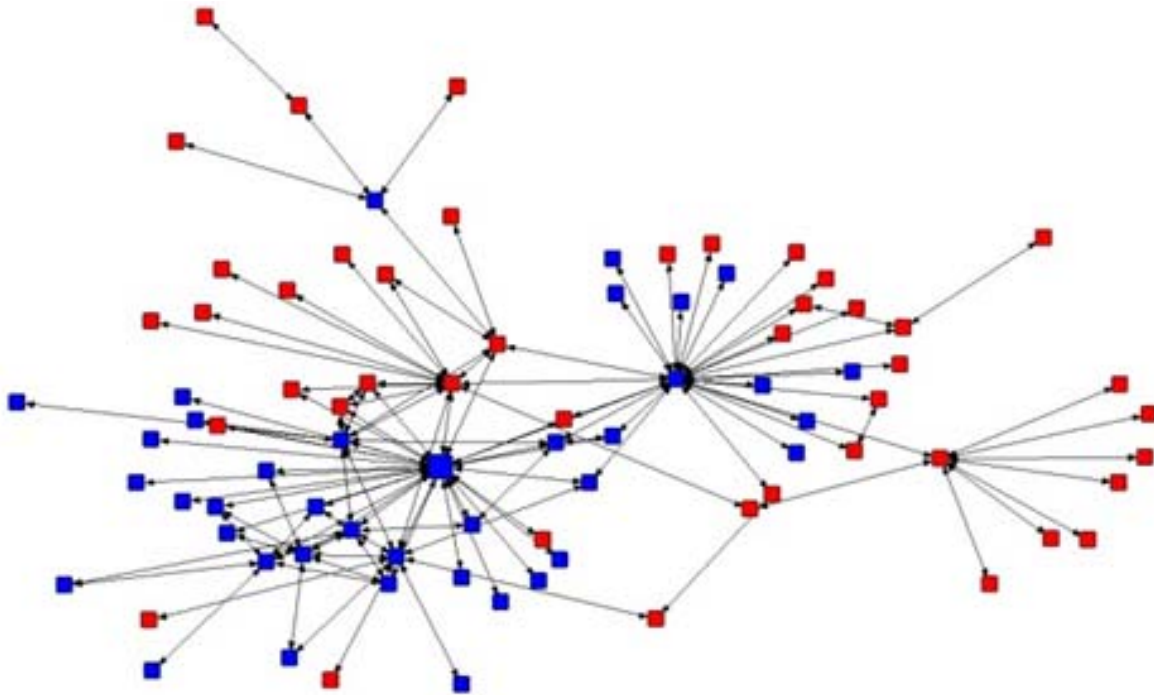
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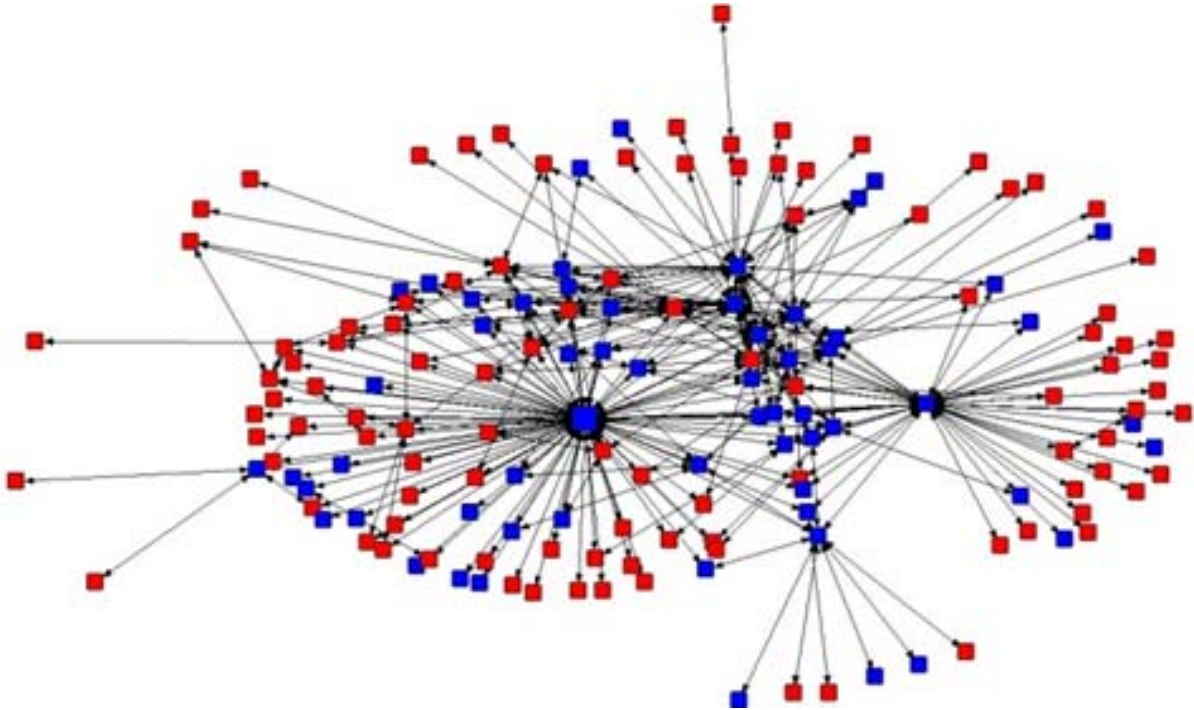
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### 13. Appendix A: Networks Pictures Regarding Essay III



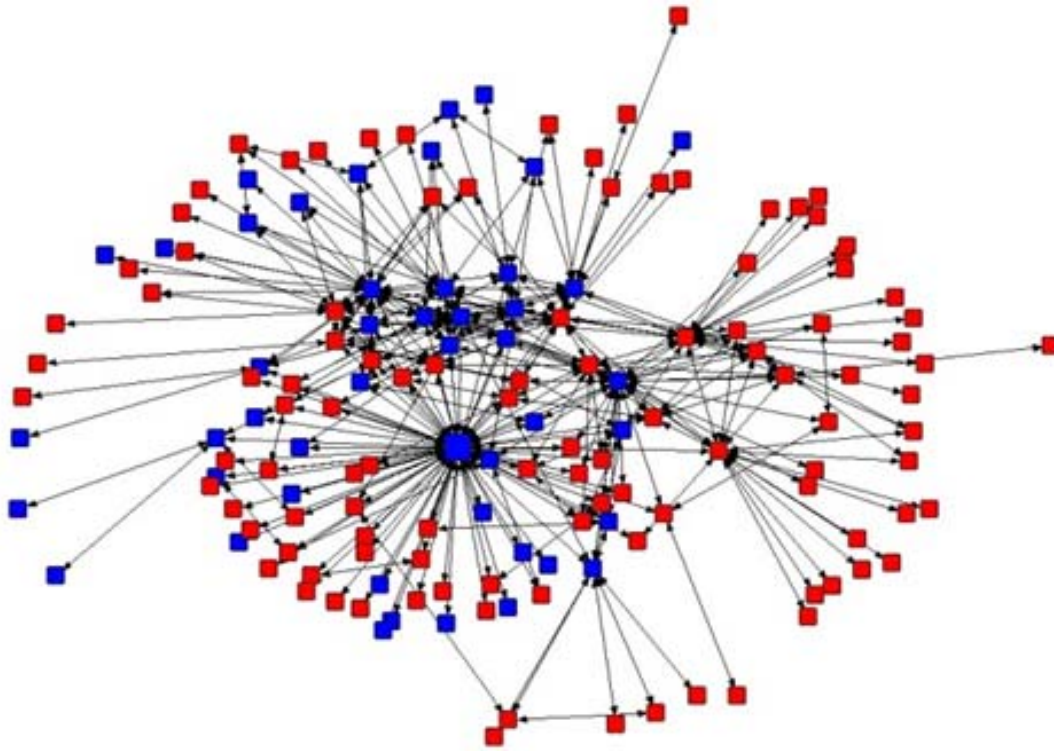
*Figure A.1: Network picture of the concept phase to illustrate the dynamics of the NPD project*

Note: Blue dots = internal actors, Red dots = external actors.



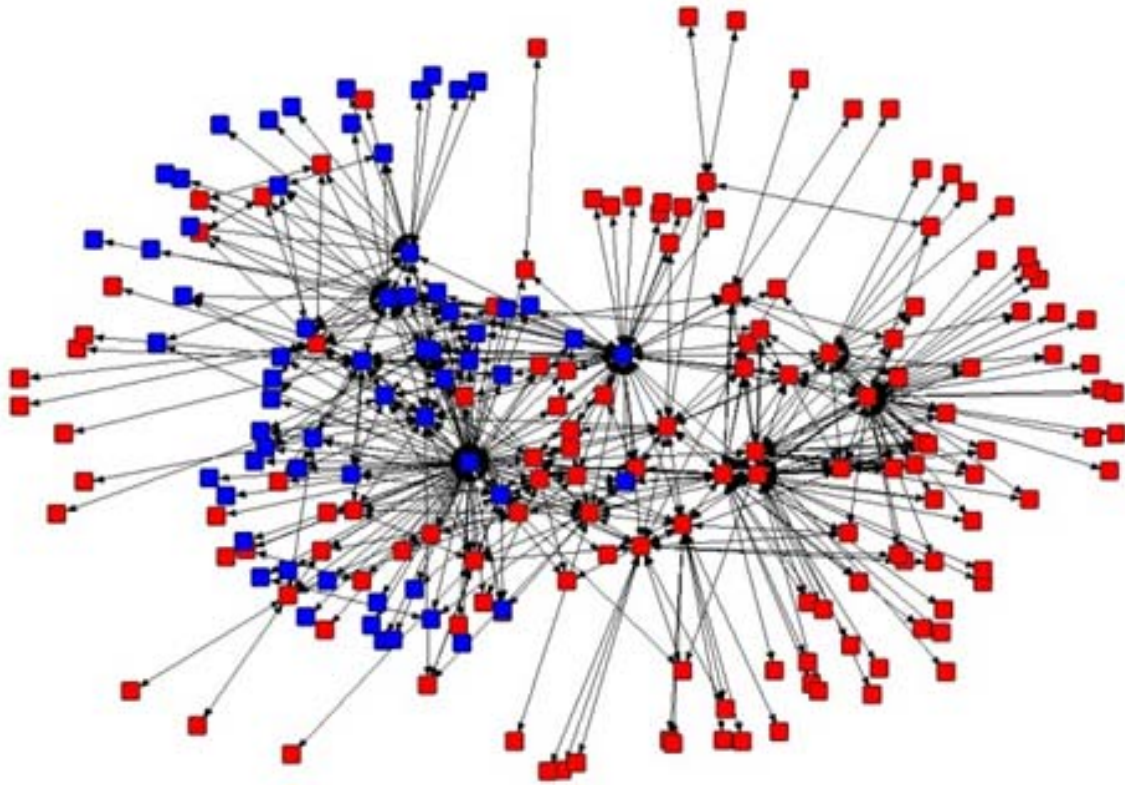
*Figure A.2: Network picture of the solution phase to illustrate the dynamics of the NPD project*

Note: Blue dots = internal actors, Red dots = external actors



*Figure A.3: Network picture of the testing phase to illustrate the dynamics of the NPD project*

Note: Blue dots = internal actors, Red dots = external actors



*Figure A.4: Network picture of the delivery phase to illustrate the dynamics of the NPD project*

Note: Blue dots = internal actors, Red dots = external actors



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