Enabling knowledge sharing
Smit - Bakker, Marloes

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2010

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

Copyright
Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

Take-down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): http://www.rug.nl/research/portal. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.
Chapter 3
Empirical research design
3 Empirical research design

3.1 Introduction

The previous chapter set up a framework of theories on how enablers affect the way the team members share knowledge. To explore whether these effects actually take place in instrument consortia, an empirical study was conducted. A comparison of the relations between enablers and knowledge sharing characteristics found through the empirical study to the propositions formulated not only gives us an insight into how the team members share knowledge, but also teaches us which theories explain knowledge sharing in the specific context of instrument consortia. This chapter describes the design of this empirical study. Chapters 4 and 5 present and discuss the findings.

The empirical study was conducted by studying two instrument consortia. This chapter starts by describing the specific field in which the empirical study is conducted and presents the two consortia studied. As indicated in the conceptual model (introduced in chapter 1), two levels are discerned at which knowledge sharing takes place: the intra-team level and the inter-team level. However, the propositions on how enablers influence knowledge sharing were formulated for the intra-team level. By gathering and studying data at both the intra- and inter team level we gain insight into knowledge sharing at both levels. For each level a different method of data gathering is used, mainly because the populations of the two levels are fairly different. Section 3.3 discusses the empirical study at the intra-team level, for which a quantitative method was used. Section 3.4 discusses and explains the empirical study at the inter-team level, for which qualitative methods were used. For each level it is explained which data were necessary, how the data were collected, and how the data were processed and analyzed.

3.2 Field of study: instrument consortia

The empirical study is conducted in the field of space science. Within this specific field of science, instruments are developed for observations in and of the universe. Over the past few decades, it has become impossible for institutes to develop these instruments on their own. Not only are the costs and financial risks too high, but the range of areas of expertise involved is too large for one institute to possess. This has set in motion a trend of institutes forming consortia which increasingly become larger, consisting of many institutes from different countries. These collaborations were formed so that participating institutes have the opportunity to utilize each other’s advanced facilities. With the founding of the European Space Agency (ESA) in 1973 (Monge et al., 2003) it became much easier to set up NPD projects with multiple partners from multiple countries. Since then the number of international collaborations has been growing. We refer to these collaborations as instrument consortia. Not only have the consortia grown in
size since the 70s, they have also had to deal with increasing technical complexity. Compared to a few decades ago, instruments now cost a lot more and rely on expertise in many different areas. The different areas of expertise include astronomy, mechanical engineering, optical engineering, electrical engineering, and software. Overall, the instrument consortia are good examples of NPD consortia for they consist of many partners, involve high costs and risks and most of all, their objective is to develop complex new products.

Within the field of space science two instrument consortia were studied. In these instrument consortia multiple organizations situated in different countries co-design and co-develop new instruments for conducting measurements in space. Because the goal of the empirical study is to measure knowledge sharing both within teams and between teams, it was preferable to find consortia with both levels present. Additionally, we wanted to include teams in highly comparable environments. Both consortia are part of larger projects (programs). Unfortunately, we were not allowed to study the entire programs as this would substantially intervene in the consortia. It would also be impossible to include the complete programs in this thesis due to the amount of work this would involve. We therefore opted for studying one consortium within each program. These consortia are representative for the other consortia in these programs. Both consortia conduct new product development projects developing measurement instruments. For confidentiality reasons, the consortia were given fictive names: project Space and project Ground.

Project Space covers the development of one of three instruments to be placed on a satellite. It is part of a larger project, which is one of the cornerstone missions in ESA’s Horizon 2000 program. There is one prime contractor, and subcontractors covering all 15 ESA member nations. Also parties in the United States are involved in the mission. Including the spacecraft, its scientific payload, the launch, and the operations, the costs of the mission total some 1,000 million Euros.

Project Ground is also part of a larger program. The program was to initially cover the construction of an antenna-network to function as one large telescope. This gave the program an astronomical background. However, the program was then changed to a more generic Wide Area Sensor Network. Functions for geographical research and studies in precise agriculture were incorporated. Then the program was split up into two main branches: a scientific branch and a technical R&D branch. Teams with expertise in astronomy, geophysics, agriculture and ICT in the scientific branch cooperate to solve the scientific issues related to the program. In the R&D branch the Wide Area Sensor Network is developed and built by subcontractors. Project Space covers the development of the network of antennas and the measurement instruments for the astronomy part. We chose to study project Ground because it is very comparable to project Space in that they both develop highly complex technical instruments for astronomical measurements, have long durations, high costs and involve many teams from different organizations. Some key aspects of these consortia are presented in table 3-1, from which it is obvious how very similar they are.
More extensive descriptions on the instruments developed in these projects are presented below. Additionally, we give more general information on the projects and describe their organizations.

**Project Space**

The objective of project Space is to develop and build an instrument to be installed on a satellite and use it for astrophysical observations. With the help of infrared and sub-millimeter rays, this satellite will take a closer look at the formation of stars and planets. Additionally, it aims to give more insight into the so-called ‘Dark Age’ of the universe; the period during which the first galaxies formed. The satellite will be better and bigger than its predecessors, due to increasing science demands and technical possibilities. Besides the instrument we focus on, there will be two other instruments on board the satellite. The instrument project Space builds will receive signals from distant star constellations and interstellar gas clouds. It has to be built for extreme conditions, a vacuum and a temperature up to with temperatures as low as 4K/-269°C or 10K/-263°C, which is close to the absolute zero (-273°C). The satellite is scheduled for launch in 2009. A rocket will send it to 1.5 million km from Earth to have a clear and undisturbed view of the universe. This place is further away from Earth than any astrophysics mission has been up to now. The minimal lifespan of the satellite and its instruments will be three years. The estimated costs for the instrument developed are around 150 million Euros.

The project was initiated when a group of international partners wrote a proposal, which was submitted to and approved by ESA. It followed years of technological research. Following ESA’s approval, more partners had to be found. Partners were chosen for different reasons, but generally they had to bring specific expertise to the project, and of course funding. The total project duration is about 15 years.

The organization of project Space is typical for instrument consortia. The organization chart is added in appendix 1. A special role is played by astronomy scientists who set up and maintain the criteria to be met by instrument. This team represents the ‘clients’ (astronomers) who use the instrument for measurements once it is launched in space. The project organization is very functionally based, because once the instrument is designed, it is split up in different functional parts that make up the subsystems. Within these subsystems the parts are further subdivided and assigned to teams as tasks, developing and building the different parts. When all the teams have built their parts, the parts are assembled and have to function together as one instrument. At the time our data collection took place, project Space was in its developmental phase. At the time of collecting the data, approximately 200 persons from 12 countries were working on project Space. During the design and developmental phases, ESA carried out reviews to keep up to date with the status of the project, to signal problems and bottlenecks in the process, and to see whether quality criteria were met.
### Table 3-1: Characteristics of project Space and project Ground

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Project Space</th>
<th>Project Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Develop highly technical measurement instrument for space (space based)</td>
<td>Develop highly technical measurement instrument for space (space based)</td>
</tr>
<tr>
<td>Domain</td>
<td>Field of space science</td>
<td>Field of space science</td>
</tr>
<tr>
<td>Project duration</td>
<td>15 years</td>
<td>10 years</td>
</tr>
<tr>
<td>Estimated costs</td>
<td>150 mln Euros</td>
<td>148 mln Euros</td>
</tr>
<tr>
<td>Number of teams</td>
<td>29 teams</td>
<td>23 teams</td>
</tr>
</tbody>
</table>

**Project Ground**

The second project involved in the empirical study aims to build a sensitive radio telescope. This radio telescope is developed for detecting objects over the entire past history of the cosmos. It can detect signals that are a thousand, million or even billion years away. The objective is to design a completely new type of radio telescope, which is based on phased array technology and that uses an innovative network design. It will be the first in a new generation of software radio telescopes, and the first that allows the measuring of the entire low frequency region of the radio spectrum (from 10 to 250 MHz, around the FM band). This telescope exists of thousands of simple antennas, spread over an area of about 150 km in diameter and linked by very fast fiberglass data transport cables. Very high energetic cosmos rays will be detected to observe the first Milky Way systems. This radio telescope is developed in collaboration with the ‘industry’. Industry is a term which is used to indicate that these organizations are outside the institutes which conduct astronomy research but belong to the business sector. In the case of project Ground, collaboration with the industry is beneficial, because the future technology requirements of radio astronomy run almost parallel to those of telecommunications and computer networking industries. It should be fully operational in 2009. The costs of this project are estimated around 100 million Euro. An additional 48 million Euro is necessary for research on the development of techniques for the instrument. In the case of project Ground, its ‘customers’ are not just astronomers. Other small instruments can also be attached to the antennas, such as seismic sensors or detectors for agricultural science. This is why other groups including geophysics, a farming cooperation, a weather institute, and universities are also included in the development of the instrument.

Within project Ground each partner is responsible for its own part of the program, but they cooperate on design and scientific aspects. A foundation has been established for the design and development of the instrument with a board of four directors, charged with project management. We conducted our data collection in the design and
development phase. At the time of data collections, around 86 people were working in 23 teams. The project organization is also very functional. For the organization chart, please see appendix 2. As in project Space, a team of scientists in project Ground is assigned to represent the interests of the scientists who use the instrument when it is up and running.

### 3.3 Empirical study at the intra-team level

Studying knowledge sharing at the intra-team level covers how team members (in sets of two) share knowledge and how the characteristics of their dyads influence the way they share knowledge. In this section, we start by describing the data necessary for testing the propositions, how the data was gathered and how the data was processed and analyzed. The actual findings and interpretation of the findings are presented in chapter 4.

#### 3.3.1 Data required

In instrument consortia knowledge is distributed as people bring different parts of knowledge to the projects, enabling the project as a whole to accomplish the overall task of developing a new product. As a result interaction is necessary in the form of knowledge sharing within and between teams in the consortia. The focus in this thesis lies on these interactions of knowledge sharing. In our research, a network perspective was adopted to study knowledge sharing interactions enabling us to represent the relational data of knowledge sharing dyads and to explore the nature and properties of those relations (Dougherty, 1992). Additionally, as argued in chapter 1, the network perspective can be applied to different kinds of actors, making it possible to study knowledge sharing both within teams as well as between teams. Also, the network perspective allows for the use of multiple theories. As pointed out, the focus is on dyadic knowledge sharing: pairs of two team members of two teams sharing knowledge one-on-one. Our approach to studying knowledge sharing is a multiple theoretical approach. Chapter 2 discusses the three social theories providing theoretical mechanisms explaining how actors share knowledge and how the enablers influence this knowledge sharing. These theories are Transactive Memory theory, Social Exchange theory, and Proximity theory.

Monge and Contractor (2003) identify the following elements of networks: agents, the attributes of their relation, their rules of interaction, and characteristics that emerge from these rules. In table 3-2, these elements are translated to our study at the intra-team level. They represent the concepts central in this thesis at the intra-team level (see the conceptual model in chapter 1). To gain an insight into knowledge sharing within teams in instrument consortia, we needed data on all of the concepts in table 3-2 and their relations, so it can be explored which propositions apply and which do not. How the data on the concepts were gathered is described below.
### Research concepts

<table>
<thead>
<tr>
<th>Elements/ concepts</th>
<th>Intra-team level</th>
<th>Inter-team level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agents</td>
<td>Team members</td>
<td>Teams</td>
</tr>
<tr>
<td>Attributes</td>
<td>Expertise overlap</td>
<td>Expertise overlap</td>
</tr>
<tr>
<td></td>
<td>Co-location</td>
<td>Co-location</td>
</tr>
<tr>
<td></td>
<td>Task dependency</td>
<td>Task dependency</td>
</tr>
<tr>
<td></td>
<td>Involvement in multiple projects</td>
<td></td>
</tr>
<tr>
<td>Rules of interaction</td>
<td>Mechanisms derive from:</td>
<td>Mechanisms derive from:</td>
</tr>
<tr>
<td></td>
<td>Transactive Memory theory</td>
<td>Transactive Memory theory</td>
</tr>
<tr>
<td></td>
<td>Social Exchange theory</td>
<td>Social Exchange theory</td>
</tr>
<tr>
<td></td>
<td>Proximity theory</td>
<td>Proximity theory</td>
</tr>
<tr>
<td>Emergent structure</td>
<td>Knowledge sharing characteristics:</td>
<td>Knowledge sharing characteristics:</td>
</tr>
<tr>
<td></td>
<td>Reciprocity</td>
<td>Reciprocity</td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
<td>Frequency</td>
</tr>
<tr>
<td></td>
<td>Multiplexity</td>
<td>Multiplexity</td>
</tr>
</tbody>
</table>

Table 3-2: Research concepts

### 3.3.2 Data collection for the intra-team level

The objective of the empirical study is to explore the effects of the enablers on the knowledge sharing characteristics between team members. Chapter 2 formulates propositions for these effects. By gathering and analyzing data at the intra-team level, we wanted to see whether these propositions were supported or not. Using a quantitative method is appropriate for this for it allows us to explore the effects and test hypotheses. Questionnaires were used to gather data. Using questionnaires enabled us to gather a large range of data on the whole population. The population in the instrument consortia was not only large but also spread over the world. The questionnaires were sent to other countries and continents. Before further explaining how the questionnaire was conducted, we will discuss how the necessary data were translated to measures in the questionnaires.

The aim of the empirical study is to study the effects of enablers on the knowledge sharing characteristics. The knowledge sharing characteristics are therefore seen as dependent variables and the (dyadic) attributes are defined as explanatory variables. How the concepts from table 3-2 were translated into measurable constructs is discussed below.

**Dependent variables: the knowledge sharing characteristics**

To collect data on knowledge sharing, the respondents were asked to indicate the team members with whom they shared knowledge and how often they shared knowledge with these team members. This was done in a way common to gathering network data. The questionnaire set out a full
roster of team members for each team. We presented the lists of team member names to the team leaders. A blank space at the bottom of each list could be used by team members to add names of team members in case of incorrect lists of team members or changes in the team’s composition. As a result, data was obtained in a form of dyadic knowledge sharing relations from each team member to his fellow team members. The relations were assigned different values for their strength; daily, weekly, monthly, or less than once a month/never.

The questionnaire distinguishes four types of knowledge content, based on a distinction between procedural and declarative knowledge. Procedural knowledge is goal-oriented knowledge to execute tasks. Declarative knowledge is factual or experiential knowledge distinguishing:

1. Know-who: knowledge of the persons in the project, for example knowing that person A is located in building B and has knowledge in a domain C.
2. Know-why: knowledge of why things are done, background knowledge of the project, for example knowing the goal at the start of the project, but also the current status of the project, et cetera.
4. Know-how: knowledge of how to do things, knowledge of procedures, processes, and expertise in how to do things.

For NPD projects, people are part of a team and have tasks to execute. These four types are included to be able to measure the multiplexity of knowledge sharing (the number of contents the team members share knowledge of). The reciprocity and frequency of knowledge sharing are based on the sharing of know-how. We analyzed the models of reciprocity and frequency for all four knowledge types, but the overall findings were similar. Know-how is the goal-oriented knowledge used to execute tasks and, because we are mainly interested in the knowledge people in the consortia use for carrying out their tasks, the choice was made to base the models of reciprocity and frequency on the sharing of know-how. Based on the knowledge sharing data the knowledge sharing characteristics were computed. The exact measures for the knowledge sharing characteristics are described below.

**Reciprocity of knowledge sharing**

Reciprocity expresses the directionality of knowledge sharing; the degree to which there is two-way knowledge sharing. A knowledge sharing dyad can be null, asymmetric or mutual. A null tie exists when no knowledge is shared between two team members. An asymmetrical tie between two team members refers to a knowledge sharing tie, where team member A approaches B, but B does not approach A for knowledge sharing. Knowledge sharing is mutual when there is a knowledge sharing tie from team member A to B and a tie from B to A. Our empirical study did not distinguish between the intensity of the knowledge sharing when considering the reciprocity of ties. This meant that we only considered whether they both indicated to share knowledge with each other without considering a possible
difference in frequency. Thus if one team member indicated to have weekly knowledge sharing and the other monthly, their relation was still mutual because both indicated to have a knowledge sharing relation with the other. As the minimal frequency measured was monthly, the values team member \( i \) and team member \( j \) assigned to their knowledge sharing were first dichotomized to either monthly (1) or not (0). After dichotomizing, the values of \( i \) and \( j \) were added up, resulting in three possible states for the dyad (D) of \( i \) and \( j \):

- \( D_{ij}=(0,0) \) Null dyad
- \( D_{ij}=(1,0) \) or \( D_{ij}=(0,1) \) Asymmetric dyad
- \( D_{ij}=(1,1) \) Mutual dyad (based on Wasserman & Faust, 1994).

**Frequency of knowledge sharing**

The strength of the knowledge sharing between two team members is represented by the frequency of knowledge sharing; how often do team member A and team member B share knowledge? Four values of frequency were measured: daily, weekly, monthly, less than monthly/never. It is not uncommon for respondents to assign different values to their relations. We opted to take the maximum of the values both team members assigned to their knowledge sharing interaction, because in the example above there is weekly knowledge sharing between \( i \) and \( j \), regardless of the direction of knowledge sharing.

**Multiplexity of knowledge sharing**

As common in social network analysis, multiplexity is used to study the overlap between multiple networks, in this case knowledge networks. As regards contents this means that we study the overlap between networks that concern different types of knowledge. This is the way we constructed the measure for multiplexity. Four content types of knowledge were distinguished: know-how, know what, know-who, and know-why. The extent to which these different contents of knowledge in ties overlap is denoted by multiplexity.

Respondents indicated the frequency of knowledge sharing with their team members for all four contents of knowledge. Similar to the reciprocity of knowledge sharing, for multiplexity of knowledge sharing we disregarded the indicated frequency and are merely interested in whether or not a particular content of knowledge is shared or not. Again the values were also dichotomized to being shared at least monthly. This resulted in a score for each type of content denoting whether it was shared (at least monthly) in the dyad (1) or not (0). The sum of these scores indicated the number of types of knowledge shared in the dyad, representing the multiplexity.

**Explanatory variables: enablers**

**Expertise overlap**

Together with key persons in both projects, a list was drawn up of areas of expertise present in the projects. In the questionnaire, the respondents were asked to indicate for each area of expertise whether it was their
specialization or not. At the bottom of the list, a category ‘other’ was added where respondent could fill in their specialization if this had been missed in the list. The full list of specializations can be found in the questionnaire in appendix 3. For each dyad, the number of overlapping areas of expertise was scored.

**Co-location**

The team leaders were asked to provide us with lists of their team members and the addresses of their work place. This was necessary for sending the questionnaires to them, but also provided us with information on the locations where the respondents worked. Based on this information, for each dyad it was scored whether the team members reside in the same location (1), or in different locations (0).

**Involvement in multiple projects**

The questionnaire asked respondents to indicate whether they were involved in other projects outside the focal project. From these data, it was possible to score for each dyad whether respondents were involved in one project (0), one of them was involved in a project outside the consortium (1), or both were involved in multiple projects (2). To be able to use these categories in analyses, the categories of one being involved in multiple projects or of both being involved in multiple projects were translated into dummies (involvement1 respectively involvement2), where the reference category was that they were both involved in this one project.

**Task dependency**

Each team member was asked to indicate whether he and the team member in question needed mutual exchange of work outputs throughout the course of their work (1) or not (0). The task dependency relations were symmetrized by taking the maximum scores.

After translating the concepts to measures, the questionnaire was drawn up. The matrices concerning knowledge sharing with other team members were personalized to include participation in multiple teams. The basic questionnaire scheme is set out in appendix 3. Before sending the questionnaire to the members of project Space and project Ground, presentations on our research were given in both projects to create more support within the projects and, thereby, positively influence response rates. Shortly after giving the presentations, the questionnaires were handed out or sent to the project members. The questionnaire was sent to all team members of project Space and project Ground in 2005/2006, together with an answer envelope. After the initial distribution of the questionnaires, non-respondents received follow-up emails and telephone calls. Table 3-3 shows the response rates for the questionnaire.
Response rates questionnaire

<table>
<thead>
<tr>
<th></th>
<th>Team leaders</th>
<th>Team members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Space</td>
<td>73.1 percent</td>
<td>39.4 percent</td>
</tr>
<tr>
<td>Project Ground</td>
<td>78.3 percent</td>
<td>43.1 percent</td>
</tr>
</tbody>
</table>

Table 3-3: Response rates questionnaire

3.3.3 Data processing and analysis

After receiving the questionnaires, they were coded to ensure the anonymity of the respondents. This was necessary because the questionnaires could not be filled out anonymously; they had to be personalized so that the respondents could see the names of their team members in the questionnaire. After coding the questionnaires, they were entered into a database and the original paper versions of the questionnaires were destroyed. Before discussing the analyses conducted, the data set is described.

In the projects 261 persons from 48 teams directly involved in NPD activities were asked to fill out the questionnaire. For more background information about the population, additional information about the respondents’ age, education, and tenure in the project was gathered. The age of the team members varied from 24 to 67 years with an average of 42 years. As the tasks in the instrument consortia are very complex and space science requires much specialization, we had expected to find highly educated people. This was indeed the case. The largest part of the persons (66 percent) has an academic degree or higher. The time they had been part of the project varied between 1 and 11 years, with an average of 5 years.

For the explanatory and dependent variables included in the study, the descriptives are shown in table 3-4. Table 3-4 for example shows that the average value for reciprocity is 0.67. To give a better idea of how each category of the dependent variables are present in the population, figure 3-1 is included. As figure 3-1a shows, the largest part of the team members share knowledge mutually. Concerning the frequency of knowledge sharing, each category is about evenly represented in the data set. There are slightly more team members sharing knowledge weekly and daily than monthly and less than monthly/never (see figure 3-1b). When sets of team members share knowledge, it is mostly not just one content they share. As can be seen in figure 3-1c, in most dyads 4 contents of knowledge are shared.

Table 3-4 also shows descriptives for the explanatory variables. The mean value for co-location is 0.73, which means that in more than half of the dyads the team members are co-located. There is also quite a part of the dyads where one of the team members is involved in projects outside the consortium. In almost 20 percent of the dyads, the team members are both involved in projects outside the consortium.
Figure 3-1: Knowledge sharing within teams in instrument consortia
<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.d.</th>
<th>Min.</th>
<th>Max.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocity</td>
<td>.67</td>
<td>.79</td>
<td>0</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>2.32</td>
<td>1.09</td>
<td>1</td>
<td>4</td>
<td>0.78**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplexity</td>
<td>2.45</td>
<td>1.56</td>
<td>0</td>
<td>4</td>
<td>-0.79**</td>
<td>-0.82**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expertise overlap''</td>
<td>0</td>
<td>.61</td>
<td>-.55</td>
<td>2.45</td>
<td>-0.14**</td>
<td>-0.03</td>
<td>0.11*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-location</td>
<td>.73</td>
<td>.45</td>
<td>0</td>
<td>1</td>
<td>-0.24**</td>
<td>0.31**</td>
<td>0.25**</td>
<td>-0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 involved in multiple projects</td>
<td>.40</td>
<td>.49</td>
<td>0</td>
<td>1</td>
<td>0.23**</td>
<td>0.21**</td>
<td>-0.20**</td>
<td>0.07</td>
<td>-0.15**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both involved multiple projects</td>
<td>.19</td>
<td>.40</td>
<td>0</td>
<td>1</td>
<td>-0.04</td>
<td>-0.05</td>
<td>0.09</td>
<td>0.09</td>
<td>0.02</td>
<td>-0.40**</td>
<td></td>
</tr>
<tr>
<td>Task dependency</td>
<td>.73</td>
<td>.45</td>
<td>0</td>
<td>1</td>
<td>-0.45**</td>
<td>-0.44**</td>
<td>0.42**</td>
<td>0.06</td>
<td>0.03</td>
<td>-0.02</td>
<td>-0.05</td>
</tr>
</tbody>
</table>

'n = 357 (dyads). Two-tailed tests are reported.
'' expertise overlap is grand mean centered (GM=.55)
* p<0.05, ** p<0.01
Table 3-4: Descriptives intra-team data
Finally the table shows that the mean value for task dependency is 0.71. This indicates that in almost three out of four dyads the team members perceive their tasks to be dependent on each other.

To explore the effects of the enablers on the knowledge sharing characteristics, statistical analyses were conducted. In general, regression analysis fits the testing of the hypotheses like the propositions formulated in this thesis, for it is an appropriate method to investigate the interactions among various variables. In this research, the focus is on knowledge sharing at the dyadic level, where knowledge is shared between two team members. However, the team members are embedded in teams and this makes the data nested. This causes the observations within the teams not being independent\(^1\). In analyzing the data at the intra-team level, it should be recognized that the dyads within the same team are all exposed to the same stimuli, which might make them likely to be more similar to one another than dyads in other groups. In a regression analysis it is assumed that (1) the random errors are independent, that (2) they are normally distributed, and (3) have constant variance. As Bryk and Raudenbush (1992) note, in this situation the assumption of independent random errors is violated because the random error component within nested data will include a group level random error which causes the observations within groups to be dependent. Additionally, the assumption of constant variance is violated because the group level random error is likely to vary across groups. For these reasons, the choice is made to use a multilevel regression analysis so that the team level is accounted for.

To analyze the relations of the enablers and the different knowledge sharing characteristics, 3 models were formulated; one for each knowledge sharing characteristic. In table 3-5, the constructs used in the data analysis at the intra-team level are summarized, together with their values and measurement scales. As the table shows, reciprocity of knowledge sharing is a multinomial dependent variable. A multinomial logistic multilevel regression was therefore used for analyzing reciprocity. Because frequency is an ordinal dependent variable, an ordinal logistic multilevel regression was used. The model for multiplexity was analyzed using a ‘regular’ multilevel regression. For the actual analysis of the models, the statistical HLM6 program was used. Restricted Maximum Likelihood was used for estimation, for this should lead to better estimates, especially because the number of teams was relatively small (Bryk & Raudenbush, 1992; Hox, 2002).

The explanatory variables at the dyadic level included in the models are expertise overlap, co-location, involvement in multiple projects, and

\(^1\) Principally, the teams are also nested in projects, but because data was collected in two projects which were very alike, not much variation was expected between the two projects. Moreover, the number of projects was too small to include it as an additional nesting level in the statistical analysis.
task dependency. To make the interpretation of the results easier, we opted to center expertise overlap (grand mean). For co-location, involvement in multiple projects, and task dependency, centering would not make the interpretation easier. Moreover, they all have natural and meaningful null values.

At the team level, no explanatory variables were included, because the reason to include the team level is solely to account for the embeddedness of the dyads within teams. We did not include variables at the team level in our framework of theories because it is not in the scope of this study to explore which variables at the team level might have explanatory value for the knowledge sharing dyads within the teams. Therefore, the team level effect was taken into account by including an intercept at the team level. Additionally, no specific effects were defined on the slopes of the variables at the dyadic level. Chapter 4 discusses the models more extensively, together with their results and interpretation.

### 3.4 Empirical study at the inter-team level

In the empirical study of knowledge sharing at the inter-team level, the focus is on how teams (in sets of two) share knowledge and how the characteristics of their dyads influence the way they share knowledge. This section discusses the data necessary for the empirical study at the inter-team level, the data collection and the processing and analysis of the data.

#### 3.4.1 Data required for the inter-team level

The objective of the empirical study at the inter-team level is to explore to what extent the effects of enablers on knowledge sharing between teams are similar to the effects within the teams. Moreover, the objective is to explore to what extent there is similarity in mechanisms explaining the knowledge sharing within and between teams. The propositions formulated in chapter 2 were concerned with the intra-team level and not with the inter-team level. The empirical findings within teams were therefore taken as the starting point for the data collection for knowledge sharing between teams. To gain insights into knowledge sharing between teams and how it is different or similar to knowledge sharing within teams, we needed to gather data on the relations of the enablers of the teams to the knowledge sharing characteristics between teams as well as data on the rules of interaction shaping these relations (see table 3-2). As argued in the description of the conceptual model, the enabler involvement in multiple projects is not included at the inter-team level. How these data at the inter-team level were gathered is described in the following.
Chapter 3 Empirical research design

3.4.2 Data collection

As mentioned, no explicit propositions are formulated for knowledge sharing at the inter-team level. Therefore, the empirical findings at the intra-team level for studying knowledge sharing at the inter-team level are used as a starting point. The emphasis is on exploring knowledge sharing between teams. For this purpose, a qualitative method is most suitable since this

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Values</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties of knowledge sharing (dependent variables):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Reciprocity</td>
<td>0= null tie 1= asymmetrical tie 2= mutual tie</td>
<td>Multinomial</td>
</tr>
<tr>
<td>- Frequency</td>
<td>1=daily 2=weekly 3=monthly 4=less than monthly/never</td>
<td>Ordinal</td>
</tr>
<tr>
<td>- Multiplexity</td>
<td>{0,1,2,3,4}</td>
<td>Ratio</td>
</tr>
<tr>
<td>Enablers (independent variables):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Expertise overlap</td>
<td>{0, ...}</td>
<td>Ratio</td>
</tr>
<tr>
<td>- Co-location</td>
<td>0= not collocated 1= collocated</td>
<td>Binomial</td>
</tr>
<tr>
<td>- Involvement in multiple projects</td>
<td>2 dummy variables: Involvement of one team member in multiple project: 0=no 1=yes binomial Involvement of both team members in multiple project(s) 0=no 1=yes binomial</td>
<td></td>
</tr>
<tr>
<td>- Task dependency</td>
<td>0 = no task dependency 1 = task dependency</td>
<td>Binomial</td>
</tr>
</tbody>
</table>
gives more in-depth information on how teams share knowledge, how the enablers are related to knowledge sharing characteristics, and the relevance of the mechanisms as described by Transactive Memory theory, Social Exchange theory, and Proximity and to what extent they actually play a role in knowledge sharing between teams.

The main method used in gathering data at the inter-team level is conducting interviews. At the start of the empirical study interviews were conducted to gain information on the issues that played a role in the consortia concerning knowledge sharing. These explorative interviews were held with 15 team leaders in project Space and 19 team leaders in project Ground. One of the results was a network of inter-team interaction. It was very difficult for the team leaders to have an overview of these relations, therefore, it was used as a starting point for further study. We mainly used more structured and extensive interviews with key persons in the project to get more insight into the knowledge sharing relations between the teams and the influences of the enablers. More specifically, these interviews focus on how expertise overlap, collocation, and task dependency of teams affect the frequency, reciprocity, and multiplexity of the knowledge sharing between teams and what the underlying mechanisms are. Since there were no previous research reports available on this subject, a new interview schedule was designed for this study based on the information requirements. Appendix 4 shows the information requirement table. The interviews are structured in three layers. It starts with open questions in the first layer and ends with closed questions in the third layer. The notion behind this is that by starting with open-ended questions, the respondents are encouraged to think openly and talk freely about their own experiences. In their answers, the interviewees most of the times did not include all the aspects for which we needed information. The second layer provided more closed questions on the aspects for which we needed information. For example, if a respondent did not mention the effect of co-location, more closed questions were posed about this relation. The questions in the third layer focused on the answers provided by asking questions like "Why do you think...?". By using this interview design, all relevant data was asked, making the interviews comparable. Appendix 5 sets out the interview scheme, with the structure and questions of the interview.

The project leaders of both consortia participated in the interviews; they were selected for their helicopter view of the projects and insights into inter-team knowledge sharing. Additionally, for each consortium a middle manager was selected with an insight into the knowledge sharing between teams from a lower level perspective. All interviews were conducted on a one-to-one basis, between researcher and respondent. Because respondents usually express themselves better in their native language, the interviews were conducted in Dutch. The duration of the interviews was between 60 and 80 minutes. In addition to the focused interviews with the project leaders and managers, we conducted observations during meetings.
3.4.3 Data processing and analysis

The interviews produced a rich amount of data, which was analyzed systematically following Miles and Huberman (1994). In preparing the qualitative analysis a code list was set up. Text-analysis matrices were also drawn up in advance to be able to compare the answers given by the respondents at a later stage. With permission from the respondents, the interviews were digitally recorded. The actual analysis and processing of the data started by listening to the digital voice recordings and transcribing the interviews. After the transcription, each interview was printed and the text fragments/lines were coded according to the four main topics; (1) reciprocity of knowledge sharing, (2) frequency of knowledge sharing, (3) multiplexity of knowledge sharing and (4) the management of knowledge sharing. Because some of the text fragments referred to more than one topic, in most cases multiple copies of the transcript were numerically coded. For each main topic a question file was produced. Subsequently, based on the codes, the transcripts were cut up into relevant sections and allocated to the appropriate topic file. By doing so, all the responses to the four main topics were assembled. To make the data more manageable, the quotations in each question file were further analyzed and broken down into a number of sub-categories and subheadings. The analyses matrices were filled with the relevant data. A careful selection was then made of the data relevant for each cell of the matrix. These decisions were made based on the table of information requirements, the context in which statements were made, and the degree to which the respondents emphasized it. Starting point for the final analysis was the findings of the quantitative study within the teams. The last step in analyzing the interview data was comparing the categorized interview data to the findings from the questionnaires within the teams. The original transcripts were also included to make sure that answers were seen within their context. During the analysis and interpretation process the data was actively searched and checked for reasons why conclusions should not be trusted, and particular attention was paid to exceptions to findings. The conclusions were verified as the analysis proceeded. The results of the qualitative study on knowledge sharing between teams are presented and discussed in chapter 5.

3.5 Summary

This chapter described the empirical design of this research. A distinction between the intra-team level and the inter-team level knowledge sharing was made in the research questions central to our research, and the empirical testing also was different for both levels. Therefore, the presentation and discussion of the empirical results will be done separately. The results for knowledge sharing at the intra-team level are described and discussed in chapter four, the results for the inter-team level are discussed in chapter five.
Chapter 3 Empirical research design