Limitations of Network Analysis for Studying Efficiency and Effectiveness of Knowledge Sharing

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Abstract: Knowledge sharing is an important part of an employee's tasks as it is one of the mechanisms through which they learn and innovate. Sharing of knowledge typically occurs in the informal networks in the organization by means of social interaction. Several authors have proposed to use social network analysis to study the knowledge sharing relations in organizations to identify potential barriers concerning knowledge sharing. Although social network analysis has been applied in several cases, it has not been evaluated if this approach results in reliable results in terms of findings problems related to knowledge sharing. One might for instance find an isolated person with network analysis, but given the context this might not be necessary a problem. The goal of this research is to validate the use of social network analysis to study knowledge networks. We have selected one particular technique, called Knowledge Network Analysis, to evaluate in this research. The Knowledge Network Analysis technique has been applied in a case study at an international product software developer to find potential barriers in their knowledge networks. To evaluate these results, a qualitative analysis has been executed afterwards by a different researcher. This analysis was based on interviews, document study and observations. To analyze the qualitative data we developed a new model called Knowledge Sharing Environment Model (KSEM), which identifies knowledge sharing bottlenecks in a structured manner. The results from network analysis and the qualitative analysis have been compared to validate the outcomes of the network analysis. Hence, six out of nine bottlenecks were validated. This research demonstrates that Knowledge Network Analysis is a good tool for the identification of bottlenecks but needs further validation in additional case studies. However, it was suggested to combine the Knowledge Network Analysis technique with another method such as the KSEM to validate and study the causes behind the identified bottlenecks.

Keywords: knowledge sharing, communities of practice, learning network, knowledge network analysis, social network analysis

1. Introduction

It is generally accepted among organizations that their employee's knowledge is their most important asset and is a source of innovation (Grant 1996; Davenport & Laurence Prusak 2000; G. von Krogh & Grand 2002). Hence, organizations manage their knowledge to spur innovation at all organizational levels and stay competitive. Early knowledge management approaches focused on codifying, storing and disseminating knowledge in the organization (Huysman & Wit 2004). However, more recently also the socialization approach got more attention (Hansen et al. 1999). This approach acknowledges that assets of an organization are often of a tacit nature and are embodied in employees in the form of experiences, skills and attitudes, also referred to as the 'deep smarts' of employees (Polanyi 1967; Leonard & Swap 2005). Sharing this knowledge in the socialization approach is typically done through social interaction between individuals or groups of individuals (Nonaka & Takeuchi 1995; Hansen et al. 1999). This type of knowledge sharing typically takes place through informal networks that we refer to as knowledge networks (Helms & Buysrogge 2005; Back et al. 2005). There is a wide body of literature on knowledge networks that focuses on different aspects. For example why do people share their knowledge (Wasko 2005), success factors in knowledge sharing (Cummings & Teng 2003), role of ICT support in knowledge sharing (Deng & Poole 2008; van Baalen et al. 2005), knowledge sharing and performance (Lesser & Storck 2001; Schenkel & Teigland 2008). Recently, there has been much attention to study the structural dimension of knowledge networks by applying a network perspective(Mueller-Prothmann & Finke 2004; Liebowitz 2005; Helms & Buysrogge 2005; Cheuck 2006). This type of research focuses on the pattern of relations of knowledge networks as a whole and/or the specific position of individuals or groups in the network. Using Social Network Analysis (SNA) techniques, the structure of the network is analyzed in order to identify problems or

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shortcomings with respect to knowledge sharing in the network. A possible problem that can be detected with network analysis is for example isolates, people with no relations to other people, or another example is a scarcely connected network resulting in slow knowledge flow through the organization because of long paths between nodes.

Although social network analysis is used by several authors to study knowledge sharing in organizations, it is unclear if this type of analysis provides a reliable and complete picture of knowledge sharing in the organization. The approach is quantitative rather than qualitative and therefore the context might be easily overlooked. An isolate that results from network analysis, for example, is not necessarily a problem if one knows that this person just joined the organization in the last week. Hence, some qualitative research concerning the knowledge network and its context is required to back up the results from network analysis. On the other hand, it might also be the case that some aspects of knowledge sharing are just simply not detected through the network perspective. The goal of this research is therefore to evaluate the limitations of network analysis for studying knowledge sharing in knowledge networks. Its limitations are evaluated by conducting a case study at an international product software developer. At the company the knowledge network was assessed quantitatively using the Knowledge Network Analysis technique from Helms (2007) and qualitatively following the approach from Bosua & Scheepers (2007). The qualitative and quantitative studies were conducted by two independent researchers, at two different points in time, and the results of both studies were compared afterwards. Comparison results in an overview of the limitations of network analysis approaches which is the main contribution of this research.

The remainder of this paper is structured as follows. First a theoretical background will be given, which focuses on the basic theories behind this paper. After that the research method is discussed in section 3. The next section, section 4, is dedicated to the case study setup and the results of the quantitative and qualitative study. Comparison of the results of the quantitative and qualitative study is discussed in section 5. Finally, the conclusions are presented in section 6.

2. Theoretical background

2.1 Social Network Analysis

Social Network Analysis (SNA) is both a domain of research and an analysis technique that originated in the field of Sociology. For a long time, sociologists were typically interested in to what extent personal and/or environmental variables explain the behavior of a person. Later, network theorists added the network perspective to the domain and they claim that behavior is also to a large extent influenced by personal relations (Wasserman & Faust 1994). Since then, the network perspective has been applied in many ways. SNA as such is a sub-domain within Sociology that studies social relations between people also referred to as the social network (Hanneman & Riddle 2005). However, SNA is also referred to as a technique for analyzing social networks that is based on graph theory. Typical measures that are based on graph theory that are used in SNA are for example connection, distance, social cohesiveness and centrality. Besides the more quantitative analysis based on graph theory, it is also possible to a more qualitative analysis that is based on a visual representation of the social network, called a sociogram. A sociogram presents people as nodes in the network and relations between people as edges between nodes. Consequently, a sociogram already reveals patterns such as connectedness of the network or social cohesiveness within and between sub-groups.

2.2 SNA applications in KM

Several authors have used SNA to study knowledge sharing in knowledge networks. The main contributions are discussed in this section and a comparison of these contributions is provided at the end.

Cross et al. (2001) where among the first to apply SNA to informal networks of knowledge sharing. They assert that work really gets done through the informal rather than through the formal relations in an organization. Their approach is based on creating a sociogram of the information flow network and analyzing general network properties, e.g. isolates, centrality and clustering. Secondly, they identified a number of dimensions to be studied: knowledge, access, engagement, and safety, in case shortcomings in the information flow network are discovered. For example, if there is insufficient

information flow within a R&D department one should analyze whether people know from each other what they know and if their colleague's knowledge is accessible for them in a timely fashion.
Mueller-Prothmann & Finke (2004) report about their SELaKT method, i.e. Sustainable Expert Localisation and Knowledge Transfer, that is based on SNA. It is intended as a "strategic tool for expert localisation, identification of knowledge communities and analysis of the structure of intra- and inter-organisational knowledge flows" (Mueller-Prothmann & Finke 2004). Their analysis focuses on studying the network of social relations and applying the following SNA concepts: degree, structural holes, bridges and hubs. Using a case study the value of the SELaKT method is demonstrated at a research organization.

Cheuck (2006) studies the application of SNA to analyze knowledge sharing at the British Council. Network data is collected by asking 30 global leaders with whom they share information, such as documents and plans, and with whom they have informal discussions about work. Furthermore, respondents have to indicate the frequency of contacts. After data collection the data is visualized in sociograms showing the daily, weekly and monthly knowledge sharing. These sociograms are then discussed with managers, after having a short introduction to the main SNA concepts, by discussing the strengths and weaknesses in the networks as observed by the managers.

Helms (2007) presents the Knowledge Network Analysis techniques that focuses on learning relations in defined knowledge areas within an organization. As the name suggests, it applies SNA to studying knowledge networks, especially learning networks. In the paper the KNA technique is presented describing the steps to take and the (SNA) measures to analyze. The analysis focuses on the absence of learning relations between people, clustering within the knowledge area, centrality and brokerage roles. Application of the technique is demonstrated in a case study at a consulting and engineering organization.

Table 1: Comparison of different applications of SNA for KM

	Focus	Type of relation	Measures
Cross et al. (2001)	Organizations or departments in organizations	Information flow	Not further specified SNA measures. Dimensions of information flow: Knowledge, Acces, Engagement, Safety
Mueller-Prothmann & Finke (2004)	Research organization to find expertise regarding funding of research projects	Social relations and their strength	SNA measures: Degree, clustering, structural holes, hubs, bridges
Cheuck (2006)	30 global leaders of the British Council in global leadership development program	Information sharing Informal work related discussions Frequency of these relations	Not further specified SNA measures
Helms (2007)	Knowledge area within an organization to detect learning bottlenecks	Learning relations and their viscosity and frequency	SNA measures: Degree, clustering, degree centrality, closeness centrality, brokerage roles, bridges

Table 1 shows a comparison of the different applications of SNA to study knowledge sharing in networks. The applications differ in the focus and goal of the analysis, the type of relation that is studied, and the width and depth of the analysis in terms of SNA measures applied. In this research the KNA technique will be used for evaluating the application of SNA to analyze knowledge networks. Main reasons for selecting this technique are its dedicated focus on knowledge networks, instead of more general social relations, the steps and measures are well described and the authors are most familiar with this method. The Knowledge Network Analysis technique is described in more detail in the following section.

2.3 Knowledge Network Analysis

Knowledge Network Analysis (KNA) is a technique to identify knowledge sharing barriers, or bottlenecks, in knowledge networks. Within KNA different types of knowledge networks can be distinguished based on the type of knowledge exchange, for example advice seeking or learning (Helms & Buysrogge 2005) (Helms 2007). The focus of KNA is a knowledge network, which refers to a group of people that have a common interest that is referred to as a knowledge area (Helms 2007). Within the knowledge network people exchange knowledge with each other related to the knowledge area. A knowledge network is distinct from a formal part of the organization such as a department or a

business unit. It is the knowledge area that binds people here and this typically crosses organizational boundaries, i.e. departments, units.
In this research we analyze learning networks. These networks focus on developing the professional skills of people in the organization by ensuring knowledge transfer from experienced colleagues to less experienced colleagues. Relations in a learning network are very similar to what is also known as master-apprenticeship relations. The goal of learning networks is to improve the skills of employees for the long term benefit of the organization. To achieve good knowledge transfers, they should preferably be of high viscosity so that rich knowledge is transferred (Davenport & Laurence Prusak 2000; Helms 2007). The viscosity scale that is used is based on Leonard & Swap's (2005) transfer techniques shown in figure 1. Viscosity increases when going from passive to active modes of knowledge transfer.

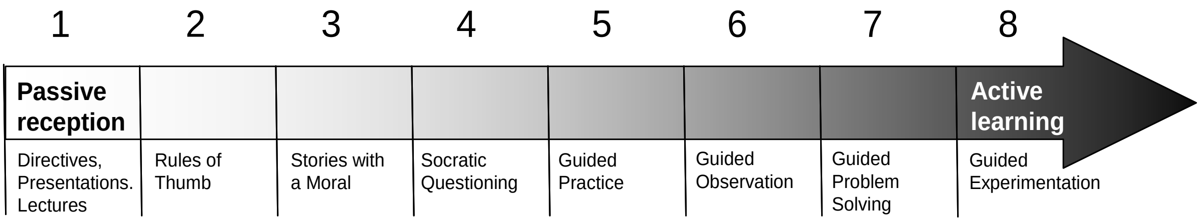


Figure 1: Scale for measuring viscosity of knowledge transfer

For analyzing learning networks, nine barriers for knowledge learning have been identified within KNA. These nine barriers can be divided in three categories: master-apprenticeship relations, sub-communities, and knowledge drain & knowledge brokers.

Master-apprenticeship

Learning will only take place if there are connections between experts and non-experts and higher skills levels are achieved when the transfers are of higher viscosity. Typical knowledge transfer barriers in this category are: experts do not transfer their valuable knowledge to non-experts (bottleneck 1) and non-experts are not receiving knowledge from experts or the transfers are of low viscosity (bottleneck 2). Furthermore, there can also be too many relations, in that case experts (bottleneck 3) and non-experts (bottleneck 4) spend too much time on knowledge transfer and learning which jeopardizes their job performance.

Sub-community

A learning network should preferably be one cohesive group so that knowledge can flow freely throughout the network. Typical knowledge transfer barriers in this category are related to the existence of sub-communities, i.e. sub-groups, in a learning network. Two possible causes for the emergence of sub communities are homophily (Zenger & Lawrence 1989) and geographic dispersion (Allen 1977; Bosua & Scheepers 2002). Sub-communities can result in an unbalanced distribution of experts over the sub communities and hence some employees might miss out on chances to learn (bottleneck 5). Furthermore, there might be no learning between sub-communities, i.e. no connections, or limited transfer, i.e. few connections or low viscosity transfer (bottleneck 6).

Knowledge drain & knowledge brokers

This last category concerns risks rather than barriers and focuses on the potential impact of the sudden (or planned in the case of retirement) departure of employees. This first risk is that of knowledge drain, Zhuge (2002) and Kiger (2005) suggest that a knowledge drain can be expected due to the departure of employees and hence the knowledge that leaves the company. A knowledge drain typically occurs when an expert leaves the organization that has no or only low viscosity knowledge transfer relations (bottleneck 7). In that case his expertise is not transferred to other and takes it with him when leaving the organization. A second risk is when employees leave that have a brokering role in the organization. A knowledge broker typically connects many people (bottleneck 8) and/or is typically a boundary spanner connecting sub-communities (bottleneck 9). The departure of knowledge brokers can lead to decreased connectedness or even disconnection of sub communities (Borgatti 2006).

2.4 Bosua – Scheepers Model (BSM)

Bosua & Scheepers (2007) have developed a model for the assessment of knowledge sharing, shown in figure 2. The model is based on three theoretical perspectives on knowledge sharing: (1) notion of a shared knowledge work context, (2) theory of distributed cognition (TDC) and its related social network (SN) theories, (3) and aspects of actor network theory (ANT). We will further refer to this model as the Bosua-Scheepers Model (BSM).

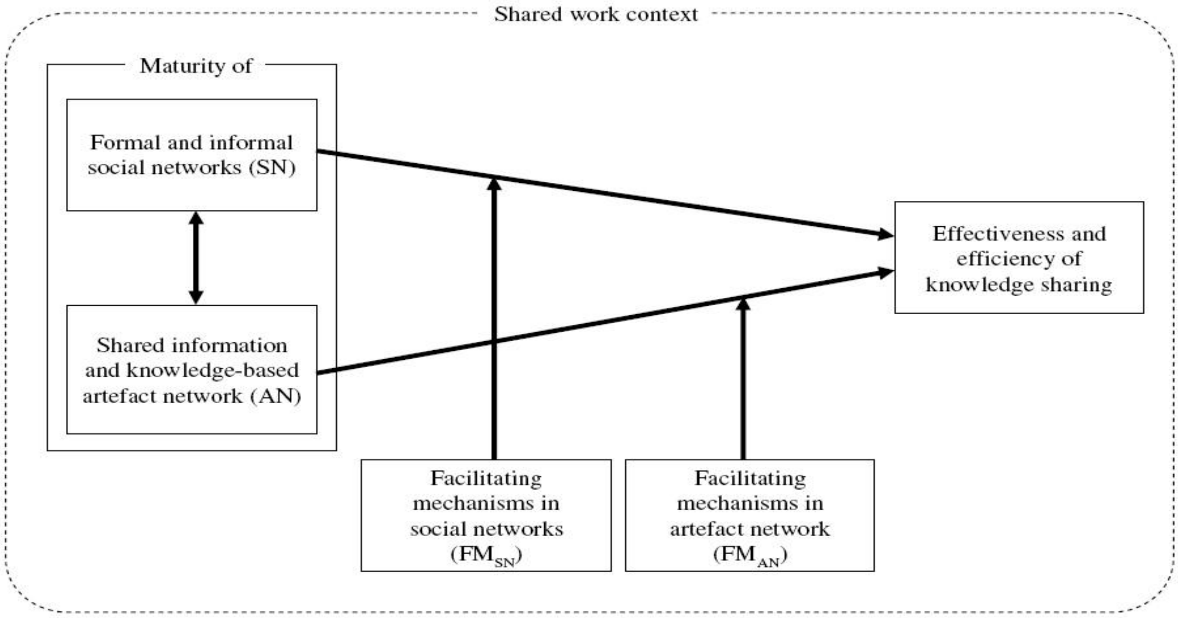


Figure 2: The Bosua - Scheepers Model (BSM)

The BSM suggests that *efficient* and *effective* knowledge sharing will take place within a shared work context if the present Social Network (SN) and an Artefact Network (AN) have an appropriate maturity and are supported by Facilitating Mechanisms (FMsn and FMan). The notion of shared knowledge work context can be compared to a community of practice in which there is a common ground and a shared repertoire of stories, tools, and terminology (Lave & Wenger 1991). The social network is defined by formal and informal relationships with other people. The artefact network is defined by relations between distributed information and knowledge based artefacts, such as lessons learned, process designs, FAQ's and best practices. Facilitating mechanisms for the social network (FMsn) are structures that enable people-to-people knowledge sharing such as CoPs, email and online meetings. Facilitating mechanisms for the artefact network (FMan) are structures that enable artefact-to-artefact connections such as taxonomies. Knowledge sharing is regarded to be effective when "relevant, useful, or meaningful knowledge is distributed between individuals within the environment, that is, that the process of knowledge sharing really takes place. The efficiency refers to the sharing of knowledge with the minimum wasted time, effort, or expense." (Bosua & Scheepers, 2007).

3. Research method

3.1 Case study approach

The goal of this research is to evaluate the limitations of network analysis in studying knowledge sharing in networks. In section 2.2 several methods/techniques for applying network analysis have been presented and as indicated the KNA technique has been selected for evaluation in this research. To evaluate the KNA technique a case study approach is applied that can be classified as a case study for validation purposes (Yin 1994; Dul & Hak 2007). Validation is achieved by applying the KNA technique at an organization and to compare the results of this analysis with the results of a qualitative analysis, based on the approach by Bosua & Scheepers (2007), at the same organization (Figure 3). The qualitative analysis is believed to provide a richer picture of knowledge sharing in the organization since it is more holistic than KNA. Hence, it is assumed that a comparison of the results of the KNA with the results of the qualitative analysis would reveal any shortcomings of the KNA technique. To avoid that the KNA results influence the qualitative analysis process or vice versa, both studies are conducted by two different researchers.

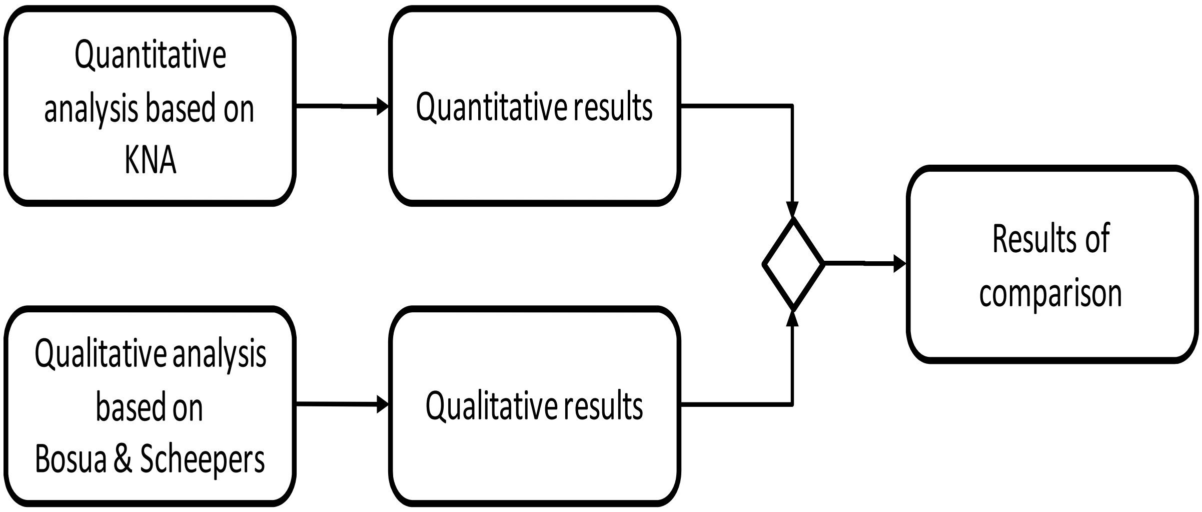


Figure 3: Outline of validation approach

Unit of analysis

The unit of analysis of the case study is the learning relations within the Wholesales & Distribution business line of an international software developer. Details about the case study company are provided in the case study findings section.

Data collection and analysis

The quantitative data collection and analysis is based on KNA and follows the protocol as has been described in (Helms 2007). A survey is used to collect data for the network analysis, it inventories: who learns from whom, how frequent these knowledge transfers takes place and what knowledge transfer techniques are applied (see figure 1). Furthermore, data is collected about the expertise level, department and function of each employee. This data is then converted to an adjacency matrix and an attribute table that are imported into Netminer II 2.6 that is used for the network analysis. Analysis of the network data concerns the bottlenecks as presented in section 2.3.

The qualitative data collection is based on the approach by Bosua & Scheepers (presented in section 2.4). Data about the social and artefact network is collected using three techniques: document review, observation, and interviews. Document review included studying various types of documents, sometimes referred to by respondents in the interviews, such as presentations, emails, knowledge documents, designs, help files, guide lines and release notes. Observation took place on the work floor as the researcher's desk was situated at the case study organization. Notes were taken incidentally when certain events occurred that seemed relevant for the research. The main source of data was the interviews. Interviews were in the form of storytelling sessions, a form of open-ended interviews were key respondents were asked to comment on the role of knowledge sharing in their daily work. They could propose solutions or provide insight into events. They could also corroborate evidence obtained from other sources. In total, fifty interviews have been conducted of one hour each. All interviews have been taped and were then analyzed by the researcher. During the analysis it was realized that a more structured approach was required to analyze all this data. This resulted in a new model that is called the Knowledge Sharing Environment Model (KSEM) and is discussed in more detail in the next section.

Comparison of quantitative and qualitative results

Both the quantitative and the qualitative analysis resulted in the identification of a number of barriers regarding knowledge transfer in the case study organization. Both lists of barriers are compared to identify to what extent the KNA technique is limited in identifying barriers concerning knowledge transfer.

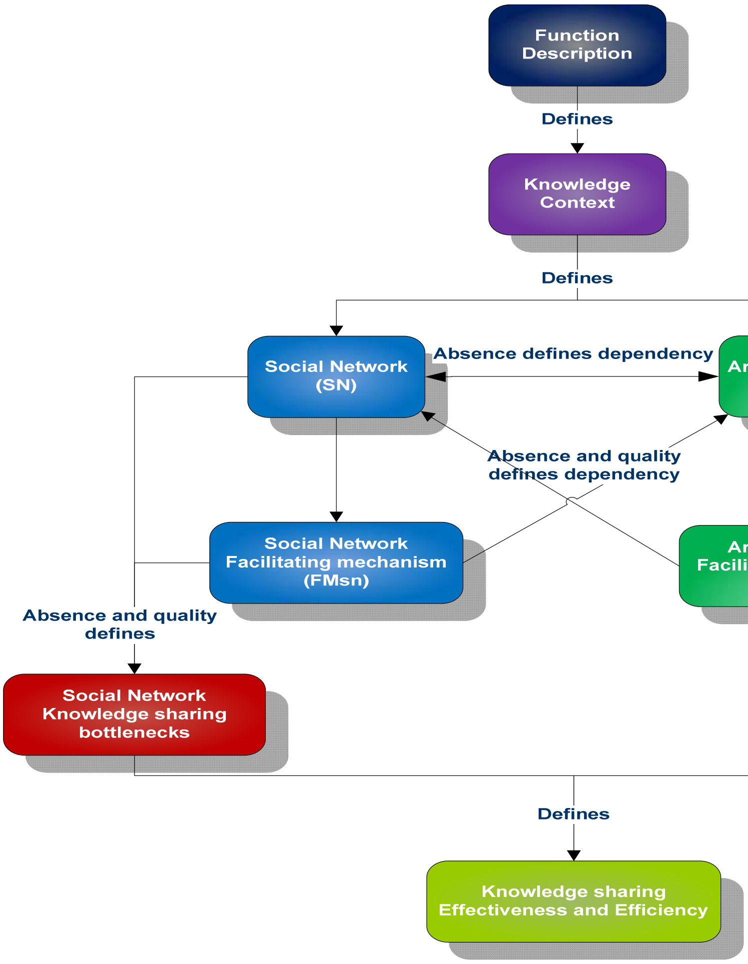


Figure 4: Knowledge sharing environment model

3.2 Knowledge Sharing Environment Model (KSEM)

In order to analyze the data gathered during the case study a new model called Knowledge Sharing Environment Model (KSEM) was developed. KSEM is based on the BSM model as discussed in section 2.2. Although it is represented differently, this model follows the same principles as the BSM and its main goal is to assess knowledge sharing. However, we extended the model with two concepts: Function Description and Knowledge Contexts. These concepts are added to the KSEM to better support and illustrate the data analysis process. A representation of the main elements of KSEM is presented in figure 4. The model and its elements are elaborated below.

Function description

The Function element concerns the function of the respondent as described by his/her job description, location, department, resources, and culture. The function description defines the day-to-day activities of individuals, which are a good starting point for knowledge sharing needs. As such, focusing on the different functions in the organization links the analysis to the right level of detail that is also understood by the organization itself.

Knowledge context

The Knowledge Context element concerns the domains of knowledge that are needed to conduct the activities related to a particular function. A knowledge domain can be defined as “a coherent cluster of insights, experiences, theories, and heuristics” (Schreiber et al. 2000). Knowledge sharing will typically take place within and across these knowledge contexts, hence focusing on the knowledge contexts brings us one step closer to identifying potential problems in knowledge sharing.

Social network, artefact network and facilitating mechanisms

The social and artefact networks concern the networks that people leverage to share and acquire knowledge. In line with Bosua & Scheepers (2007), the social network refers to the network of social relations between people through which knowledge might be transferred using some form of interaction, while the artefact network refers to a network of information and knowledge-based artefacts, in either analogue or digital form, which can be consulted directly. Facilitating mechanisms act as moderators within and between Social and Artefact Networks. Examples of mechanisms for Social Networks are knowledge brokering roles or incentive schemes while examples of mechanisms for artefact networks concern technologies to support the capturing, structuring, and disclosure of knowledge.

Knowledge sharing bottlenecks

The absence and quality of the networks and the facilitating mechanisms define the knowledge sharing bottlenecks. In other words, these bottlenecks are directly defined by the absence and quality of the Networks and Facilitating Mechanisms. Furthermore, these bottlenecks define the effectiveness and efficiency of knowledge sharing.

Knowledge sharing effectiveness and efficiency

In this research we stick to Bosua & Scheepers' definition of effective and efficient knowledge sharing. Knowledge sharing efficiency refers to the amount of time, effort, and expenses needed to share knowledge. And knowledge sharing effectiveness refers to the usefulness of knowledge that is shared. Both efficiency and effectiveness of knowledge sharing are directly influenced by the knowledge sharing bottlenecks that are found.

Impact of bottlenecks

Not every bottleneck that is found will have the same impact on knowledge sharing efficiency and effectiveness. To get more insight in this impact a Bottleneck Impact measure has been developed. This measure is not an exact calculation of the impact of the bottleneck in financial terms, but concerns a relative measure for the knowledge sharing that it hinders for a particular business function. The reasoning behind this is: if a function is largely dependent on a specific knowledge context and the sharing of knowledge in this knowledge context is heavily dependent on for instance the social network, then a bottleneck related to the social network has a large impact on knowledge sharing efficiency and effectiveness in that function. Consequently, the Bottleneck Impact (BI) for a bottleneck X is calculated as follows:

$$BI_X = RI_{SN/AN} * KC_Y$$

where RI is the relative importance, as a percentage, of respectively the Social and Artefact Network and KC is the relative importance, as a percentage, of the Knowledge Context Y. As bottlenecks might influence the efficiency or effectiveness of knowledge sharing (or both), each bottleneck is classified as an effectiveness or efficiency bottleneck. When it concerns the time, effort or expense it takes to gather knowledge, it is an Efficiency Bottleneck (EfyB). When it concerns the quality of the knowledge, i.e. usefulness, it is an Effectiveness Bottleneck (EfsB). Finally, calculation of the bottleneck impact gives good insight into the magnitude of the identified knowledge sharing bottlenecks. Such insight is important for prioritizing knowledge sharing bottlenecks.

KSEM Graph

The KSEM Graph is an instantiation of the generic model, as shown in figure 4, for a particular function. It provides an overview of the knowledge contexts, social and artifact networks, and bottlenecks and their impact. An example is shown figure 6 and is explained in more detail in section 4.2.

3.3 Validity issues

In designing a case study approach several validity threats have to be addressed (Dul & Hak 2007). Four common threats have been identified by (Yin 1994): construct validity, internal validity, external validity, reliability. Table 2 below shows how these validity threats should be addressed according literature (2nd column) and how this study addressed the validity threats (3rd column). Internal validity is not included in this table as it concerns testing causal relationships in a case study which is not the goal of this study.

Table 2: Overview of how validity threats are addressed

Validity threats	Solutions according to Yin (1994)	Solutions used in this research
Construct validity	Multiple sources of evidence	Data collected using surveys, interviews, observations, and document review
	Establish chain of evidence	Original data and analysis and findings are documented
	Have informants review the case study results	Outcome of the network analysis is discussed with the KM owner in the organization. The results from the KSEM analysis has been checked with the respondents
External validity	Use rival theories in a single case	Quantitative and qualitative approach towards analysis of knowledge transfer are evaluated in this research
	Replication in multiple cases	One case study used and limitations are discussed in the conclusions
Reliability	Use case study protocol	A case study protocol is documented and is based on KNA and KSEM
	Use case study database	All collected data is archived and results are documented

4. Case study findings

4.1 Case study organization

The case study was conducted in the Wholesales & Distribution business line of an international product software developer. The company operates in 10 European countries, the United States, and Canada, its headquarters are located in The Netherlands. At the end of 2006 the company had around 2,700 employees. The research was conducted at one of the product lines, which develops software for the wholesale sector and employed 99 people at that time. We selected a single product line because it can be considered as a small product software company itself, which is responsible for all activities concerned the development, sales, and implementation of a software product. Much of the knowledge transfer is therefore considered to take place in this product line around their software product and working practices. Furthermore, within the product line they actively promote knowledge transfer in learning networks, which they refer to as knowledge circles. In total, there are 17 learning networks within the product line and each one focuses on a particular topic such as EDI, Sales or Third Party Apps.

4.2 Quantitative analysis: KNA

Data for the network analysis was collected using a survey that was distributed among the 99 employees of the product line. In total, 80 people responded to the survey which results is considered sufficient for the network analysis. Data was collected using an online survey tool, i.e. LimeSurvey, and network analysis has been conducted using Netminer. With Netminer, one can analyze typical network characteristics such as number of connections (i.e. degree), centrality, and sub-communities (i.e. clustering). The tool also supports in making visual representations of the network, as shown in figure 5.

The quantitative analysis involved the application of the KNA technique on three of the learning networks that are considered representative in terms of the number of employees and number of departments involved. Here the analysis of one of these networks is discussed, analysis of the other two networks is done in a similar manner. The learning network discussed here is the Service & Maintenance network consisting of eighteen people from five different departments.

Master-apprenticeship

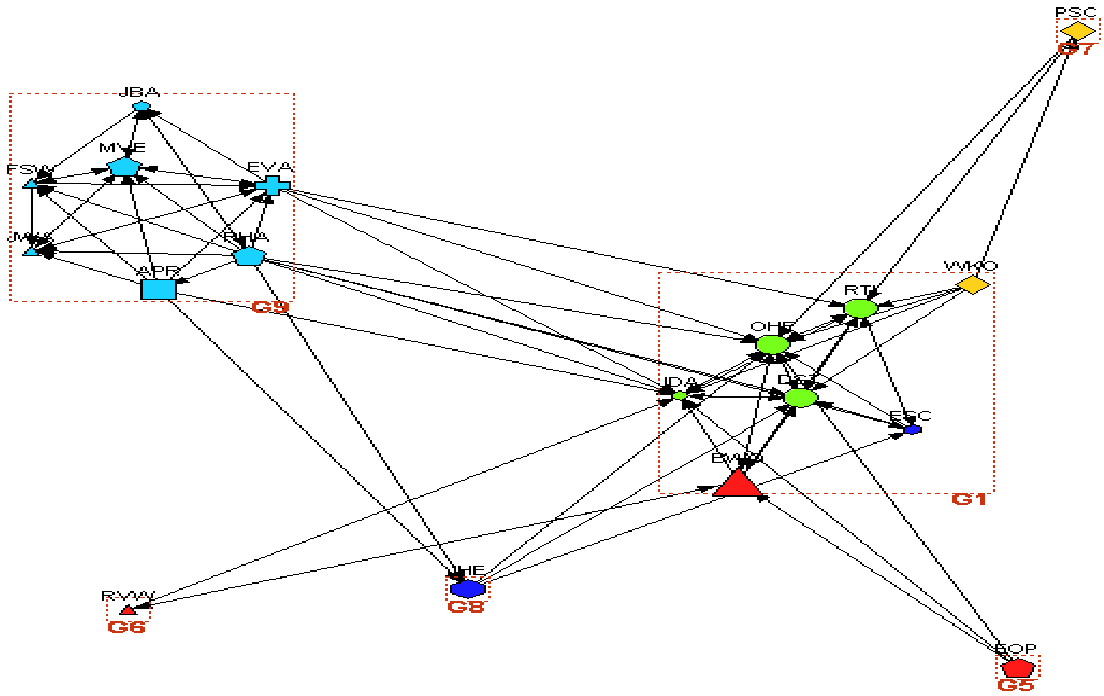
This involves studying the relations between people of different expert levels, i.e. expert, specialist and trainee. Knowledge is expected to be transferred from more experienced employees to less experienced employees with high viscosity. Both too less learning (bottleneck 1 and 2) and too much learning (bottleneck 3 and 4) are considered undesirable. This is hard to see in the network graph in figure 5 and is determined by analyzing the adjacency matrix. Based on this analysis the four bottlenecks are detected.

- Two specialists [PSC, WKO] transfer their knowledge with low viscosity with other less expert people.
- All eleven specialists and one trainee [RVW] receive knowledge from at most two experts.
- One expert [BWO] and one specialist [RHA] transfer their knowledge to more than four less expert people.
- Two trainees [FSW, JDA] receive knowledge from more than four experts.

Sub-community

Sub-communities are undesirable in a learning network as it hinders the free flow of knowledge through the network. The Girvan Newman algorithm is applied to test what clustering can be de found in the data (Girvan & Newman 2002). The result is shown in figure 5 and considers a clustering that is significant (i.e. based on discriminant analysis as implemented in Netminer II 2.6). It shows that in total 6 sub communities can be detected within this learning network. By analyzing the expertise of members of the sub-communities and the transfers between the communities the following bottlenecks are detected.

- Unbalanced distribution or insufficient of expertise over sub communities, i.e. only one expert [BWO] in community G1.
- Two communities [G9, G5] only transfer knowledge but do not receive knowledge.



Legend: color of nodes: location of person;
size of node: expertise level of person; shape of node: function of person

Figure 5: Learning network for maintenance and service

Knowledge drain & knowledge brokers

There is a risk that knowledge drain will occur if expert people with few or no relations leave the company. Another risk is central people or knowledge brokers leaving the organization because the learning network might fall apart. By analyzing isolated experts, closeness centrality and brokerage roles the following bottleneck are detected.

- There is one person [RHA in G9] that is far more central than other persons based on closeness centrality. His departure will result in a loss of knowledge transfers for people dependent on him.
- Departure of the most central person [RHA in G9] affects knowledge transfer to G1 as he is responsible for 3 out of 7 relations from G9 to G1.

4.3 Qualitative analysis: KSEM

After the quantitative analysis another researcher conducted the qualitative analysis. Interviews were the main source of data collection and were in the form of storytelling sessions, a form of open-ended interviews were the respondents are asked to comment on the role of knowledge sharing in their daily work. Documents used in this research were in the form of presentations, emails, knowledge documents, designs, help files, guide lines and release notes. They were mainly used for exploration, better understanding of concepts and to ground statements made by the respondents. Finally, observations, such as presentations, knowledge sessions, and day-to-day work of employees, played a big role in defining the researcher's perspective. It gave insight on how the knowledge sharing took place in practice and helped to place the collected data in the right perspective.

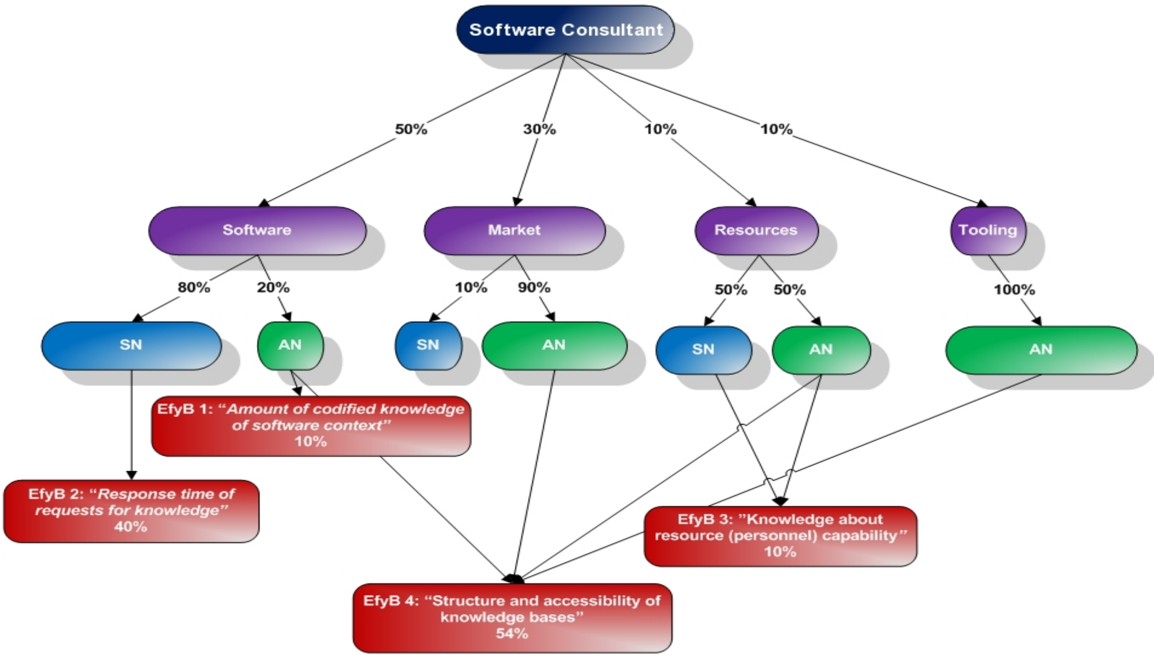


Figure 6: KSEM Graph - Impact of knowledge sharing bottlenecks

Once all the data was collected it has been analyzed using KSEM. This resulted in eight KSEM graphs, one for each (major) function within in the business line. Here only one KSEM graph will be presented and the results are briefly discussed for illustration purposes. The example concerns the Software Consultant who is involved in software implementation projects and most of the time works on the customer's location. Its tasks consist of: situation analysis, customer consultancy, planning, software implementation, testing and going live. Due to the variety in its tasks a software consultant depends on four different knowledge contexts: software, market, resources, and tooling, as shown in the KSEM graph in figure 6. Software consultants use both the artefact and social network to acquire software knowledge. However, a bottleneck related to the artefact network (EfyB1) concerns the lack of codified software knowledge. Besides training documentation and the support consultant's knowledge base, no other form of open and accessible codified software knowledge could be observed. Software consultants indicated that this is not sufficient for their work. Consequently, they turn to their social network to acquire the desired knowledge by asking other colleagues for knowledge. Questions are typically asked by e-mail and several software consultants said to personally store the replies for later reference because of the valuable responses they receive. A disadvantage that is observed here (EfyB2) concerns the sometime slow response rate of colleagues to their questions. Based on interviews and observations of the software consultants it was estimated that the software knowledge context forms approximately 50% of their complete knowledge context. Furthermore, it was estimated that for 80% of the time, the software consultant uses its social network for the acquisition of the software context. This means that bottleneck EfyB2 affects 40% (0.5x0.8) of the total knowledge sharing interactions of a software consultant. A similar calculation for EfyB1 shows an impact of 10%.

Table 3: Overview of identified KSEM bottlenecks

Bottleneck	Support Consultant	Software developer (R&D)	Software developer (Cust.)	Information analyst (R&D)	Information analyst (Cust.)	Project manager	Software Consultant	Technical Consultant	AVG
1. Availability of persons		64%	48%	66%	57%				58.8%
2. Departmental barriers	56%	62%	51%						56.3%
3. Accessibility of codified				24%	39%	36%	54%	76%	45.8%
4. Response time of							40%		40.0%
5. Missing knowledge						65%	10%		37.5%
6. Quality of codified	24%	22%	4%	15%	24%				17.8%
7. Amount of codified		14%	12%				10%		12.0%

After creating individual KSEM graphs, all bottlenecks were compared and re-labeled if it turned to be our similar bottlenecks but under a different name. After re-labeling the bottlenecks for the difference functions can be compared as is shown in Table 3. The rows represent the bottlenecks, the columns the functions and each cell contains the impact of a bottleneck for a function. In the most right column the average impact of the bottleneck is shown. The top two bottlenecks are both related to social networks. Employees scoring on these two bottlenecks are used to sharing knowledge face-to-face, because they usually find themselves in the proximity of those they need to share knowledge with. Furthermore, they all reside in the same building and therefore the use of other facilitating mechanisms becomes obsolete.

5. KNA validation

Table 2 presents an overall overview of the validation of the KNA technique. It shows if evidence is found in the qualitative study to support the bottlenecks found by KNA. The first column corresponds to the bottleneck number as they were validated. The second column tells whether evidences could be found to validate the bottleneck. The third column tells whether the bottleneck was actually validated. And the fourth column gives a short explanation why the bottleneck was validated or not. The results as shown in table 4 show that the bottlenecks as identified by KNA could be partially validated by the qualitative analysis. We will elaborate a bit more on the validation of three bottlenecks, B1, B5 and B6, below.

Table 4: The bottleneck validation matrix

Bottleneck	Evidence found	Validated	Reason
B1	Y	N	Different knowledge contexts; Liability to detect and assess the artefact network
B2	N	N	Not enough evidence found;
B3	Y	Y	Bottleneck was supported with results of both interviews and direct observations;
B4	Y	Y	Bottleneck was supported with interviews results;
B5	Y	Y	Bottleneck was supported with results of both interviews and direct observations;
B6	Y	Y	Bottleneck was supported with results of both interviews and direct observations;
B7	Y	Y	Bottleneck was supported with interviews results;

Bottleneck	Evidence found	Validated	Reason
B8	Y	Y	Bottleneck was supported with results of both interviews and direct observations;
B9	Y	N	Bottleneck wasn't identified in the KNA;

Bottleneck 1 concerns the lack of knowledge transfer of two specialists, PSC and WKO, which was not considered a bottleneck in the qualitative analysis, i.e. was not validated. Both specialists, that don't transfer knowledge to less expert colleagues, are sales consultants from the Pre-sales department. From the interviews it became clear that this lack of knowledge transfer can be explained by the different knowledge contexts of sales consultants and the other members, i.e. support consultants, R&D software developers, R&D information analysts, customization software developers, customization information analysts and software consultants, of the learning network. For sales consultants market and customer knowledge is an important knowledge context, but for the other members of the learning network it is the software knowledge context. So although the software consultants are experts in the Maintenance & Service learning network it mainly concerns the sales and market knowledge and this is only limitedly required by the other members. Furthermore, evidence from documents and direct observations showed that this knowledge can also be acquired through the artefact network, e.g. presentations. Hence, the artefact network works as a sort of back-up or substitute for the social network. Summarizing, contrary to the findings of KNA, there are at least two reasons to believe that this situation isn't a bottleneck. An interesting finding here is the role of the work related knowledge contexts to understand the different interests of employees, from different functions/departments, concerning their participation in the knowledge network. Furthermore, an interdependency between the social and artefact network was found that was also observed in other situations.

Bottleneck 5 and 6, on the other hand, could be validated using the findings from the qualitative analysis. It concerns the unbalanced distribution of experts over sub-communities and the lack of viscous knowledge transfers between sub-communities. First of all, the main reason for the sub-communities, based on KNA, was the geographical dispersion of people. Many respondents acknowledged this in the interviews and one respondent mentioned: "This [ed. existence of sub communities] was the case when we were dispersed over the three buildings. Now it's a whole different story. Everybody is in the same building and it is easier now for us to share knowledge." Secondly, network analysis found that there was only one expert in one of the sub-communities and very limited high viscous knowledge transfer between the sub-communities. This bottleneck is validated based on an observation and interviews. Managers at the software development and the support department, i.e. the sub-communities in KNA, recognized this problem. Although, they knew that employees of both departments used facilitating mechanisms such as the phone or email to contact each other, these mechanism were regarded as interruptions and besides don't support high viscosity knowledge transfer. Therefore, they decided to plan weekly meetings focusing on face-to-face knowledge transfer and expertise regarding the software context.

6. Conclusions

Based on the validation presented in this paper, it can be concluded that KNA has a great ability to identify knowledge sharing bottlenecks. The bottlenecks that were found at the case study organization were largely supported by the findings from the interviews and observations. Nevertheless, it was found that KNA focuses on the symptoms rather than the underlying causes. Therefore, there is also room for improvement concerning the interpretation of KNA results to reveal causes of the identified bottlenecks. A first improvement that is proposed considers the identification of multiple knowledge contexts within a learning network. Section 5.1 showed how multiple knowledge contexts within a learning network helped to understand that it is not necessarily a problem if expert people do not share their knowledge with less knowledgeable colleagues. Therefore, the knowledge context dimension is considered a valuable extension of KNA.

However, the knowledge context dimension alone is not sufficient to explain every cause. As demonstrated by the examples in section 5.2, the origin of a bottleneck can also be the presence or absence of an artefact network. These causes are necessary to know in order to provide solutions for the identified bottlenecks. However, these aspects cannot be revealed using KNA because it requires explanative abilities concerning the artefact network which KNA currently does not have. Therefore, the combination of KNA, with another qualitative method such as KSEM is proposed. KSEM can be used as a tool for analyzing an individuals' knowledge sharing environment in order to study possible causes of the identified bottlenecks. Besides improving the correctness of the interpretations, the qualitative explanative method also empowers the abilities of the KNA.

7. Future work

In this research the KNA technique has been validated in one organization. To increase the reliability of KNA it is suggested to validate KNA also in other organizations. Another idea for further research is to extend KNA by including knowledge artefact networks (as found in section 5.2) so that it also covers the codified dimension of knowledge sharing. This requires that knowledge artefacts are modelled as nodes and that relations between artefacts are presented as edges. It should be researched how the analysis of such a network can be used to identify bottlenecks regarding efficiency and effectiveness of knowledge sharing and how it can be related to the social network part of KNA.

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